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A Half Century of TEACHING SCIENCE *and* MATHEMATICS

A Half Century of Science and Mathematics Teaching

Central Association of Science and Mathematics Teachers

FIFTIETH ANNIVERSARY VOLUME

A Half Century of Science and Mathematics Teaching

A summary of significant developments in the teaching of science and mathematics during the first half of the twentieth century, and an account of the development of Central Association of Science and Mathematics Teachers and the part it has played in these developments

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Preface

THE PROBLEMS of education in the United States during the past half century have been largely those of adjustment to profoundly changing physical, economic, political, and social conditions.

During this half century, the population of the nation has increased from seventy-six million to one hundred forty-five million.

In 1900, we were predominantly a rural people. In 1950 we are more nearly a nation of city dwellers, and every decade sees a further movement from country to city.

In 1900, the high school enrollment of the United States was five hundred fifty thousand. In 1950, the high school enrollment is ten times five hundred fifty thousand.

In 1900, the person who owned an automobile was for that reason a conspicuous individual in any community. Today automobiles are far more numerous than horse-drawn vehicles were half a century ago.

In 1900, there were neither airplanes, nor radio, nor home refrigerators, nor farm tractors, nor automatic home heating, nor electric sweepers, nor motion pictures, nor DDT, nor penicillin, nor vitamin pills. There was no profession of psychiatry, nor a relativity theory, nor communism, nor enfranchised women, nor easy divorce, nor common international travel, nor the aftermath of two world wars, nor atomic bombs.

The half century of the existence of Central Association has seen almost nation-wide raising of the compulsory education age limit. School curriculums have been expanded, enriched, and improved. The number of modern, well-equipped school

buildings has greatly increased. Health programs, counselling programs, testing programs, athletic programs, survey programs, and social programs have been added.

The above paragraphs are a brief and incomplete enumeration of the material and social changes which are the background against which Central Association of Science and Mathematics Teachers has developed.

New philosophies and new statements of old philosophies of education have arisen during this half century, some to survive and win acceptance, some to make their contribution and then become a page of history.

Every material and social change of these fifty years has added new problems for education in general and for mathematics and science teachers in particular. How clearly have members of Central Association of Science and Mathematics Teachers seen these problems? How carefully have we analyzed and evaluated them? How wisely have we planned for their solution? How courageously have we contended for improvement? With what vision have we planned for the future? What sacrifices of time, thought, and money have we made in order that our program might be effective?

These are some of the questions which we pose for ourselves in this volume. We spread here the record so that he who runs may read. We read it with some pride and some regret, pride in our achievements and regret for our failures. Out of both our successes and failures, let us form a new resolution to serve the needs of our country and the young people who will be its responsible citizens in the years ahead.

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Central Association and The Journal

By the turn of the century, science had set its roots deep in the society of America. Scientific discoveries became topics of everyday conversation. The experimental method of science rapidly gained popular approval and acceptance. A golden age of science—a phenomenon of western civilization—was at hand.

This rapid growth and public acceptance of science, coupled with a rapid increase in the enrollment of secondary schools, stimulated new development in the teaching of mathematics and the sciences.

Central Association of Physics Teachers

On the crest of this wave of scientific interest and emphasis, a group of physics teachers from schools in the Central States met in Chicago in the spring of 1902 to consider the organization of an association of physics teachers. A committee of three was appointed which, after further consideration of the matter, called a meeting to be held in Chicago, June 7. Twenty-five schools were represented at this general meeting. It was a business meeting with no program of papers, and here it was that an organization entitled the Central Association of Physics Teachers was formed. A constitution was adopted and the following officers elected:

President—Charles H. Smith, Hyde Park High School, Chicago

First Vice-President—Franklin H. Ayres, Central High School, Kansas City

Second Vice-President—Charles F. Adams, Central High School, Detroit

Secretary—Charles E. Linebarger, Lake View High School, Chicago

Treasurer—Eugene C. Woodruff, Lyons Township High School, LaGrange, Illinois

The Thanksgiving recess and the spring vacation were selected as the times for holding meetings of the Association. Preparations for the next meeting were at once begun by the various committees with the result that the meeting held November 28 and 29 at Lewis Institute, Chicago, proved very successful as to attendance and interest.

The fact that the scientific impetus which stimulated the organization of physics teachers influenced other areas is evidenced in the action taken by the Mathematics Section of the Educational Conference of Academies and High Schools in November of the same year. These teachers were concerned with the improvement of instruction in mathematics by introducing the laboratory method and by bringing about a closer correlation of mathematics with other subject matter of the curriculum, especially physics.

Beginning of Central Association

To this end, they set in motion plans which resulted in a petition, signed by the teachers of mathematics, being presented at the Thanksgiving session of the Physics Association. This petition embodied the request that a larger association to include all the sciences and mathematics be considered. During the winter, plans were formulated to include mathematics and the other science fields in the April meeting of the Physics Association. This meeting, held at the Armour Institute of Technology in Chicago, April 9-11, 1903, was the culmination of the unification movement. The larger organization was named the Central Association of Science and Mathematics Teachers. The Physics Association became the Physics Section, and Biology,

Chemistry, Earth Science, and Mathematics Sections were added. This session marked the second and last meeting of the Physics Association and the only spring meeting of the Central Association of Science and Mathematics Teachers.

The third meeting, held November 27-28, 1903, in the Northwestern University Professional School building at Lake and Dearborn Streets in Chicago, was the first program meeting of the larger organization. By now, the Association was well established and the general pattern of its meetings was set up much in the manner that it remains today. Dr. John Dewey, then Professor of Philosophy and Education and Director of the School of Education at the University of Chicago, made the leading address. His subject was "Disciplinary Value of Science Teaching."

Following the third meeting, the close correlation of science and mathematics was evidenced in the papers presented. This correlation has remained a major theme in the meetings of the Association to the present time.

In 1916, Professor Robert D. Carmichael of the University of Illinois presented a paper on "The Relation of Mathematics and Physics in the High Schools of the Future." The following year President W. O. Thompson of Ohio State University continued the discussion with the topic "Immediate and Ultimate Aims of Science and Mathematics Teaching." In 1920, Chief Chemist W. D. Richardson of Swift and Company discussed "The Relation of Science and Mathematics to Business and Industry." In 1923, Dean Charles P. Emerson of Indiana University School of Medicine spoke on "Pre-Medical Mathematics and Science," and Dr. H. E. Slaught of the University of Chicago talked on "Mathematics and Other Sciences." At the 1928 meeting, Professor Lewis Karpinski of the University of Michigan presented a paper on "Mathematics and the Progress of the Sciences." Dr. Slaught came back in 1931 with "Numbers: the Language of Science." In 1933, Dr. Ernst R. Breslich gave an address titled "Coordinating the Activities of the Departments of Science and Mathematics in Secondary Schools." Three years later, Dr. Frank William Bubb of Washington University, St. Louis,

addressed the Association on "The Influence of Geometry upon the Physical Sciences." The 1937 program included two papers on the subject: "The Significance of Mathematics in Science and Art" by Dr. Louis Brand, and "Mathematics and Science" by Dr. Charles N. Moore, both of the University of Cincinnati. Dr. Arthur H. Compton of the University of Chicago continued this theme in 1941 in his discussion of "Application of Mathematics to Science."

We have recently witnessed the coming of the atomic age and are familiar with the contribution of combined physical science and mathematics to it. Where trial-and-error experimentation could not be applied, mathematical calculation served as the research procedure. Thus, the correlation of scientific and mathematical endeavor which supplied the impetus for the organization of the Central Association of Science and Mathematics Teachers was later to usher in the atomic age.

An even clearer expression of the universality of interest in the sciences and mathematics is evidenced in the nature of the organization of the Central Association. While sections preserve the identity of specialized fields, the general programs serve to broaden the knowledge and viewpoints of the group as a whole.

A highlight of the tenth program held in Cleveland, Ohio, was an address by Dr. Harvey W. Wiley, Chief Chemist, United States Department of Agriculture, "Food Facts Which Every Citizen Should Know." Dr. Wiley thanked the Association for the high honor which it had conferred upon him in making him an honorary member of the Association. He was, however, entitled to some consideration since he was a teacher in the Indianapolis High School, now Shortridge High School, as far back as 1871-72 when the high school was housed in the old frame church which was Henry Ward Beecher's church during his pastorate in Indianapolis. In those days, teachers of science were expected to know a little of everything, and Dr. Wiley was called upon to teach chemistry, botany, physiology, biology, zoology, higher mathematics, the upper classes of Latin and Greek, and to fill in the places of any teachers who happened to be absent, as well as to conduct the morning exercises by reading a few chapters from the Bible.

Nature of Programs of Central Association

The Central Association has become unique among teachers' organizations by making its programs inspirational and informative rather than purely pedagogical in nature. This characteristic reflects the vision of the teachers who founded it. Like those who have continued the Association, they were superior in the art of teaching and felt greater need for information relative to current developments in the fields of science and mathematics than for discussions on pedagogical routines and methods. The Association has served as a meeting ground for representatives of scientific organizations, research institutions, and teachers of science and mathematics. Special problems related to teaching have been discussed in sectional meetings, but they have never dominated the program of the general meetings. This, perhaps, accounts for the inspiration received by teachers of mathematics and science through their contact with vigorous and productive leaders in these fields. It accounts, also, for the fact that its members have been close to the trends in science and mathematics and have expressed these trends in the programs of the Association.

Mention has already been made of the interdependence of mathematics and other sciences. However, specialists in almost every field of endeavor have found that they must turn to the mathematics for assistance. Sometimes they need the mathematics to assist them in interpreting data and again in the search for new relationships. Many scholars have an interest in mathematics because they admire the power of mathematical expression, the beauty of mathematical generalization, the constancy of mathematical truths, and the rigor of mathematical thinking.

Programs of the Central Association have always featured outstanding papers on mathematical subjects. In 1927, Professor Charles H. Judd of the University of Chicago presented a paper on "Recent Experimental Studies which Throw Light on the Nature of Mathematical Thinking." In 1929, Dr. Ernest P. Lane, also of the University of Chicago, spoke on "Definition and Classification of Geometries." Other papers include: "Some Relations between Mathematical Thinking and Thinking in

Other Fields," Professor Clarence E. Comstock, Bradley Polytechnic Institute, 1930; "The Unity of Geometry and Algebra," Professor Lewis C. Karpinski, University of Michigan, 1932; "Mathematics and Reality," Dean Charles S. Slichter, University of Wisconsin, 1933; "The Relation of Mathematics to Art, Poetry, and Music," Dr. David Birkhoff, Harvard University, 1935; "Functional Thinking," Dr. E. R. Hedrick, University of California; "The Contribution of Mathematics to General Education," Professor Raleigh Schorling, University of Michigan, in 1939; "The Mathematical Interpretation of History," Dr. Harold T. Davis, Northwestern University, 1940; "Functional Thinking in the Teaching of Mathematics," Dr. J. S. Georges, Wright Junior College, Chicago, 1945.

Both world wars focused attention on mathematics as shown in "Mathematics in the War" presented by Professor Leonard E. Dickson of the University of Chicago before the convention in 1918; and "The Nation Calls for Mathematics," presented by Dr. William L. Hart of the University of Minnesota in 1942.

An interesting example of the excellent service performed by the Central Association in keeping its members acquainted with current developments is the area of sound recording, analyzing, synthesizing, and reproducing. An important group of lecture demonstrations on this subject starts with one presented by Dr. Dayton Miller of Case School of Applied Science at the Cleveland meeting in 1910. Dr. Miller attached a fine quartz fiber to the center of a diaphragm, such as is used in a telephone receiver. This fiber was passed around a very small shaft, mounted like the balance staff of a small watch, and then attached to a spring. A minute mirror was fastened to the shaft. When sound waves caused the diaphragm to vibrate the fiber transmitted the vibration, in the form of an oscillation, to the shaft and mirror. A ray of light, reflected from the mirror, pictured the vibration on a screen. By interposing a rotating mirror the vibrations were spread out on the screen and a graph of the sound wave could be photographed. He showed the effect, on the pictured wave, of overtones and harmonics by using a set of tuning forks mounted on resonators. To exhibit the graph

of an ideal musical tone, he blew notes on a gold flute he himself had made from gold brought from the Klondike.

In 1926, Mr. O. T. Schrage of the American Telephone and Telegraph Company gave a paper on "Transmission of Pictures Over Telegraph and Telephone Wires." Another paper along this general line came in 1931 when Dr. William Braid White, Director of Acoustic Research of the American Steel and Wire Company, spoke on "The World of Tone and the World of Noise." "Selected Topics in Acoustics with Experiments" by Dr. Floyd Rowe Watson, University of Illinois, came at the 1935 meeting.

In 1938, in 1941, and again in 1946, Dr. James Owen Perrine of American Telephone and Telegraph Company presented lectures illustrated with large amounts of apparatus. The first was called "Words, Wires, and Waves." In this lecture he demonstrated long-distance telephone equipment with the process of amplification. He exhibited vacuum tubes that would produce oscillations in an electric current which could be converted into tone. He produced tones that were both above and below the audible frequencies. He demonstrated the speed of an electric impulse, sending a spoken signal on a round trip to New York by telephone and amplifying the signal so the audience could hear it on its return. The time required for the transmission was observable between the voice and the returned signal. In 1941, Dr. Perrine's topic was "The Artificial Creation of Speech." By means of quite elaborate apparatus, and with an assistant to operate the keys, very realistic imitations of human speech were produced by combining electrically created elements of sound. In 1946, Dr. Perrine's address was titled "Radar and Microwaves" and described the nature of radar and its military use in World War II.

Programs Related to Medicine

The work of the medical profession has been closely allied with scientific progress. The life expectancy of a man born in 1900 was forty-nine years. In 1949, it was sixty-six years. While direct application of the scientific research which has brought

about this progress is made by very few of the members of the Association, there has always been a keen interest in the subject. A few of the many papers in this general field are: "The Role of Chemistry and Physics in the Living Organism," by Dr. George W. Crile of the Cleveland Clinic in 1932; "The Value of Animal Experimentation," by Dr. Arno B. Leukhardt of the University of Chicago, in 1935; "The Contribution of Chemistry in the Field of Hormones to Health Control," by Dr. Fred Conrad Koch of the University of Chicago, in 1938; "Those Drugs of Ours," by Dr. Frederick F. Yonkman of Ciba Pharmaceutical Products of New Jersey, in 1943; and "Antibioticals," by Dr. Brooks Fortune of the Eli Lilly Company of Indianapolis, in 1948.

Conservation Education

In common with many other citizens of the United States, members of Central Association have long been acutely concerned about the misuse of our natural resources. This public concern had been cultivated by Henry David Thoreau, Ralph Waldo Emerson, John Burroughs, James and John Stuart Mill, and many other economists and writers. There were national and state organizations whose purpose was to increase concern regarding the wasteful depletion of resources and secure legal and voluntary regulations. However, these organizations generally directed their attention to adults.

There came to be a feeling on the part of many persons that conservation must become a habit of thinking and attitude familiar to all from the time they were capable of thinking about any matters of private and public concern. This meant that the problem was one for the schools. Some members of Central Association became militant about conservation and called for effective acceptance of the responsibility of educational leadership. At the 1930 meeting of the Association in Milwaukee, the biology section voted to recommend to the Association that it accept leadership in developing a program of scientific conservation education. At the business meeting, a resolution was passed which provided for the appointment of a committee of

not less than five members to consider the details of such a program. The president, Dr. Glen W. Warner, appointed to membership Fred Schriever of Milwaukee, chairman, P. K. Houdek of Robinson, Illinois, O. D. Frank of Chicago, J. L. Cooprider of Evansville, Indiana, and R. B. Simon of Hudson, Ohio.

Mr. Schriever addressed a number of questions to members of the committee in an attempt to assemble and clarify ideas for an effective program. The committee wisely decided not to try to work too rapidly but to take time to educate members of the Association and cultivate an understanding of the problems. One point in the program of the committee was to try to get conservation speakers on sectional and general programs at the annual meeting. Another point was to try to get the conservation point of view accepted by teachers of science, mathematics, social studies, and English so that by means of reading, scientific studies, the making and reading of graphs, and by numerous other means, conservation would become a habit of thinking. The committee held that it was not necessary to organize separate courses for the teaching of conservation nor to do any violence to accepted courses in school curriculums. Realizing the need for the training of teachers to present conservation facts and cultivate conservation attitudes, they recommended that teacher training institutions should modify their courses where possible to provide for adequate preparation of teachers.

Realizing that teaching materials were an urgent necessity for a general program of conservation education, the Association sponsored the preparation of lists of available materials and distributed these widely.

The Conservation Committee was very effective in bringing about within the Association a situation favorable for constant attention to the important program which was its chief interest. It arranged to have a Conservation Group meeting as a regular feature of the annual program. For a number of years, it sponsored an annual luncheon. Many of the outstanding conservationists of the nation were listed on programs of the Association.

Even before the organized activities of the conservationists,

Central Association had recognized conservation as an important issue. In 1914, Dean Eugene Davenport of the University of Illinois appeared on the general program to speak on the subject "On the Application of Science to Agriculture." The following year, Professor Cyril G. Hopkins of the University of Illinois presented a paper on "The Application of Science to Soil Fertility."

After 1930, papers on conservation appeared regularly on sectional or general programs or on both, and during the last seven years there have been papers every year, usually more than one.

A paper that had great influence was that of Professor William G. Albrecht of the University of Missouri in 1943. His subject was " 'Grow' Foods or only 'Go' Foods According to the Soil." Professor Albrecht forcefully pointed out that where the soil is lacking in essential elements, usually because of gross mistreatment, the crops are deficient in food values so that animals and human beings alike suffer from malnutrition even though there is an abundance of bulk from gardens and farms. Conservationists speak of this as the "hidden hunger."

Another speaker who left an indelible influence was the novelist, Louis Bromfield, who appeared on the program in 1944. His subject was "Conservation in Everyday Life." As a practicing conservationist on his Malabar Farms in Ohio, Mr. Bromfield told a hopeful story of how land that has long been mistreated can be restored and made once more into a national asset.

The conservation program of the Association has borne some very notable fruits. One of these was the passage in 1935 of a Conservation Education Law in Wisconsin. This law provides for compulsory teaching of conservation in the common schools of the state and the compulsory offering of such instruction in every high school. It provides for the inclusion of conservation in training courses of teachers attending institutions in the state. It also provides for the distribution to schools of materials of instruction. To Mr. Schriever and his committee should go much credit for helping to create a situation favor-

able to the passage of this law. Mr. H. J. Parmley also rendered great service in the work of shaping up the law and helping to secure its passage.

Programs of Geographic Interest

The programs of the Association have made a particularly valuable contribution to a geographic background for its members. With considerable frequency, explorers and world travelers have given lectures, usually illustrated, about remote and little known parts of the Earth. Among these contributors are: Dr. Rollin D. Salisbury of the University of Chicago who, in 1913, spoke on "In and About Patagonia"; Dr. John F. Hayford of Northwestern University who spoke of "The Great Landslides of the Panama Canal" in 1916; Dr. Rollin T. Chamberlin of the University of Chicago who, in 1925, described "Mountain Climbing in the Rockies"; Professor William H. Hobbs of the University of Michigan who told the 1927 convention about "Exploring the North Pole of the Winds"; Dr. William M. McGovern of the Field Museum and Northwestern University whose subject in 1929 was "Asia in World History"; Dr. Lewis Francis Thomas of Washington University, St. Louis, who gave in 1936 "An Analysis of the Geographic Aspects of the South Seas"; and Dr. Maurice Ewing of Columbia University whose topic in 1948 was "Recent Studies of the Atlantic Ocean Basins."

Not only have the members been given opportunity to know about this planet, but, although the Association has no section on astronomy, several papers have dealt with progress in this field. Among these papers are: "Recent Work on the Ether Drift" by Dr. Dayton C. Miller of Case School of Applied Science in 1925; "The Expanding Universe" by Professor Edward A. Fath of Carleton College in 1930; "Wonders of Starland" by Dr. Phillip Fox of the Chicago Planetarium in 1931; "Modern Views on the Structure of the Universe" by Dr. F. K. Edmondson of Indiana University in 1939; and "Astronomy and Its Place in the Junior High School Curriculum" by Dr. Harry E. Crull of Butler University in 1948.

Probably no phase of the programs of the Association has

been more rewarding to the teacher with limited opportunity to learn of scientific research than that dealing with atomic structure. The officers of the Association have been able to secure the services of many informed speakers who have regularly reported the phenomenal developments in this field. Typical titles are: "Some Recent Physical Theory" by Professor Albert P. Carmen of the University of Illinois in 1912; "Recent Advances in Chemical Knowledge" by Professor William D. Harkins of the University of Chicago in 1924; "What Things are Made of" by Dr. Arthur H. Compton of the University of Chicago in 1929; "The Structure of the Atom" by Professor Warren Weaver of the University of Wisconsin in 1930; "The Significance of Atomic Energy" by Dr. Henry Bohn Hass of Purdue University in 1945; "Atomic Energy" by Dr. George Callingaert of the Ethyl Corporation of Detroit in 1946; and "The Control and Beneficial Uses of Atomic Energy" by Dr. Samuel K. Allison of the University of Chicago in 1947.

Social Responsibilities of Science

Recent utterances of scientists concerning the control of atomic energy are indicative of a significant change of attitude on the part of research scientists concerning the use of their discoveries. For many years, in fact ever since science became established as a rational discipline, the goal has been the discovery of truth. The discoverer assumed no responsibility for the use to which his contribution was put. It was believed that knowledge, in the long run, would benefit mankind. The technician, the engineer, and the business man were left to apply discoveries to the service of society, and to the politician was given the task of controlling them. Now research has developed an instrument so powerful that it is feared that it may be the means of destroying the civilization that produced it. We now have the phenomenon of the atomic scientists attempting to arouse a public consciousness to the danger and to stimulate democratic society to develop adequate controls to protect itself from this destruction. Attention is focused on the fact that scientific research has been an important factor in creating social

problems which pure science cannot solve. This attitude was reflected in 1939 in a paper titled "Science, Ethics, and War" by Dr. Earl Raymond Hedrick of the University of California; in 1946, "Science, General Education and the National Welfare" by Dr. Frederick L. Hovde of Purdue University; and in 1947, "Today's Science and our Basic Philosophies" by Dr. Percy Julian of the Glidden Company of Chicago, and "Some Ethical Implications of Science" by Dr. Andrew C. Toy of the University of Illinois.

The proceedings of the Central Association reflect an earlier change of attitude on the part of scientists that is probably equally significant. The method of research, once established and understood, seemed so fruitful and powerful that its followers became convinced that it had the solution of many, if not all, of man's problems. As a result, some scientists became almost arrogant. No occasion arose for the general public to challenge this thesis until the Darwinian theory of organic evolution seemed in conflict with religious beliefs regarding the origin of the Earth and man. That conflict led to much bitterness. State legislatures sought to solve the problem by law, and school boards, by rules. The teaching of evolution was banned in many secondary schools and higher institutions. The Bible story of creation was arrayed against the theory of evolution and people were invited to take sides.

The discovery of radioactivity, natural transmutation of certain elements, and the conversion of matter into energy convinced scientists that they have not yet found satisfactory solutions for all the problems involved in orienting man in the universe. Hence, scientists are more humble and less assured. In the meantime, a more liberal and better informed public has learned to respect the integrity of scientific knowledge and has laid aside its hostility. This development is evident in the following papers which were presented on Association programs: "Are Science and Religion Incompatible?" by Dr. Gerald B. Smith of the University of Chicago, 1925; "The Race of Man in the Universe," by Dr. George K. Fay of the University of Iowa, and "What Should Be the Attitude of High School Teach-

ers toward the Theory of Evolution?" by Professor Horatio H. Newman of the University of Chicago, in 1926; "The Geologic Path of Life," by Professor Carey Croneis of the University of Chicago in 1931; and "The Coming of Man," by Dr. Fay-Cooper Cole of the University of Chicago in 1939.

In 1927, Dr. William D. MacMillan of the University of Chicago presented a paper entitled "The Evolution and Dissolution of Matter." In this paper, Dr. MacMillan considered a form of inorganic evolution. He presented a theoretical cycle involving the conversion of matter into energy in the cores of large stars, the radiation of this energy to the outer regions of space, its reconversion there into matter, and finally the sweeping up again of this matter into larger and larger accretions until it found its way into a star large enough to cause a transformation into energy. While not based on experimental evidence, this paper implied the development of atomic energy that was exploited almost a score of years later.

Growth of Central Association

In a slightly different sense of the word, the Central Association itself has been an evolution. It began modestly. At the meeting held at the Northwestern University Professional School Building, November 25-26, 1904, Eugene C. Woodruff, Treasurer, reported a balance of $35.52. The yearbook of that year, known as the "Fourth Yearbook" was the first to print the list of members. There were 272. Of this number, 105 (39%) were from Chicago, 59 (21%) from Illinois outside of Chicago, 61 (22%) from Ohio, 13 (5%) from Wisconsin. Indiana had 10, Michigan 8, Iowa 6, Minnesota 4, Missouri 3, and Colorado, Nebraska, and North Dakota each had one.

Growth in membership has been steady and slow. For several years past it has been over one thousand. Chicago, as would be expected, has furnished many members. The influence of the Association has been quite out of proportion to its size. This is true probably for two reasons. The members have been unusually influential because they were among the more progressive and alert of the profession. The Journal, reporting the

programs, has been read by a much larger group of teachers than attend the programs or maintain membership.

Although the Journal, *School Science and Mathematics,* has always been the official Journal of the Central Association of Science and Mathematics Teachers, only since the Association was incorporated on July 18, 1928, under the laws of the State of Illinois, has it been owned, managed, and published by the Association. Purchase was made possible by the sale of debentures to members of the organization and a few commercial firms. Purchasers of these debentures had small assurance that the Association would be able to redeem them. Debentures were bought because of the loyalty of the members and their desire that the Association continue to render the greatest service possible. As long as any of these debentures were outstanding, three of the five members of the Journal Committee had to be approved by the holders of the majority of the principal amount of the debentures.

During several years following 1928, every effort was made by the Board of Directors of the Association to economize in all departments so that all available funds could be used to retire debentures. During that period, no traveling expenses of members of the Board of Directors or committees were paid from Association funds. Many loyal members went to considerable personal expense to promote the welfare of the Association. Although some such expense is now paid from the Association treasury, a major part is still borne by the members themselves so that the Association may provide as much service as possible to mathematics and science teachers at a low membership fee.

The history of Central Association of Science and Mathematics Teachers has, indeed, been an inspiring one educationally, as you see; but the cement which has made its texture doubly strong has been the fine spirit of friendship and cooperation that has increased and broadened with the years. One sees old friends from near and far greet each other across the lobby of the convention hotel. Newcomers are quickly drawn into friendly groups and encouraged to feel a personal interest in all the activities. No barriers have been permitted to

hinder the interchange of good fellowship which prevails. This fellowship pays dividends in Association strength.

Many elements have contributed to this solidarity. The local committees in the convention cities have vied with each other to make the meetings memorable, each in its own way, with entertainment, beautiful decorations, interesting favors, and well planned luncheons and banquets. For many years meetings were held in vacation-freed school or college buildings, but in 1932 the Association, under the guidance of its president, Mr. F. R. Bemisderfer, established the precedent of convening in hotels.

The book and supply companies, too, have added greatly to the conventions with their excellent exhibits and their support through numerous memberships. Their courteous, interested, and friendly representatives have brought color and enthusiasm on many occasions and have broadened horizons for many of their visitors.

Countless are the small personal incidents which each member likes to recall when reminiscing with old friends about conventions of the past, but few ever fail to recall the beaming satisfaction with which Mr. O. D. Frank accepted the enthusiastic appreciation for the beautiful apples he so loved to distribute late on Friday afternoons in the exhibit room. One recalls meetings where lights in ball rooms were too dim to see the speaker, rooms too cold for comfort, crowds too large for some of the scheduled meeting places, projection machines that grew indifferent under the stress of programs—dozens of such incidents make up each one's own personal history of the Association conventions. The unifying thread running through it all, however, has been the fine, friendly give-and-take of all its members, both new and old, tolerance for imperfections, and praise for work well done.

This friendly camaraderie has prompted several out-of-door spring sessions of the Association where groups of members comparatively near each other met together. Mention of a few typical ones will arouse memories of many others to the reader, no doubt. The Cleveland membership sponsored a long-

remembered Maple Sugar Stir in Hudson, Ohio, one year. The Indiana group panned for gold in the creeks of Brown County one rainy spring Saturday; still other times under the leadership of Dr. John Potzger, Lake Cicott called the Indiana group northward; Pine Hills and Turkey Run State Park attracted them to western Indiana; historic Brookville, Metamora and the old Whitewater Canal, with fossil hunting in the surrounding hills, took them southeastward.

So, through the years Central Association of Science and Mathematics Teachers has brought its members an abundance of leadership in the fields of science and mathematics. It has helped in strengthening of the correlation between the two subjects. It has exerted a strong influence for scholastic accomplishment in educational circles in the fields of its activity. It has furnished friendly and lasting contacts for all who will accept it. In short, Central Association of Science and Mathematics Teachers has been the product of the efforts and hopes of those sincere men and women who believe in the value of science and mathematics in the world, and who strive to keep abreast of developments in their fields so that they may be inspiring in their classrooms.

The Journal

Its Beginnings

Half a century ago the infant magazine *School Science* was born. It was destined to mature into *School Science and Mathematics*, the present official organ of Central Association of Science and Mathematics Teachers. The times which *School Science* was intended to serve were educationally quite different from those now served by the mature publication. Half a century ago it was generally believed that limited knowledge of the rudiments of a few branches of the common school curriculum was all that was important for ninety-five percent of the citizens. High school was believed to be intended only for the few who were destined to enter the professions. College education was quite beyond the hopes or even the serious

desires of most of the population. The largest of the institutions of higher learning enrolled only a few hundred students at any one time.

Today the schools must fulfill the highly important obligation of training the leaders of the country and at the same time must meet the needs of all boys and girls through the entire period of their rapid physical growth and mental and moral development. Whether the founder of *School Science* foresaw any of these important changes it would be impossible to say. That he must have had some vague notion of the changes to come is shown by his opening message.

To The Science Teacher

The object and aim of "School Science" is to give you all possible aid in your teaching. It will keep you posted on scientific matters having a more or less direct bearing on education. It will furnish you inspiration and information.

"School Science" is to be by and for the science teacher. You are invited to send in articles, notes, news, and suggestions,—anything that may be of value and interest to the teacher of science.

"School Science" cannot accomplish its mission without your support. Subscriptions sent in the inserted "currency carrier" are at your risk. Will you not co-operate in this movement towards a bettering of science teaching? Address all communications to

School Science
Unity Building, Chicago, Ill.

The first issue of *School Science* appeared in March, 1901, edited by C. E. Linebarger and a group of twelve associate editors consisting of the following: George W. Benton (chemistry), Shortridge High School, Indianapolis, Indiana; E. C. Case (geology), State Normal School, Milwaukee, Wisconsin; H. N. Chute (physics), High School, Ann Arbor, Michigan; R. H. Cornish (physiography), Girls' High School, New York City; E. L. Hill (biology), Collegiate Institute, Guelph, Ontario, Canada; E. L. Morris (botany), Western High School, Washington, D.C.; Louis Murbach (biology), Central High School, Detroit, Michigan; George W. Myers (astronomy), The Chicago

Institute, Chicago, Illinois; Lyman C. Newell (chemistry), State Normal School, Lowell, Massachusetts; William H. Snyder (geography), Worcester Academy, Worcester, Massachusetts; George F. Stradling (physics), N. E. Manual Training School, Philadelphia, Pennsylvania; Rufus P. Williams (meteorology), English High School, Boston, Massachusetts.

The first issue consisted of twelve short articles in thirty-five pages, eight pages of "Notes" on science topics—zoology by E. A. Bedford; biology, author not given; geology by E. C. Case; chemistry by Lyman Newell; five book reviews; a list of six books received; and three pages of Reports of Meetings, correspondence, etc.; five pages of advertising plus the cover pages.

It is interesting to note that the body of this first issue consisted of twelve short articles. The editor does not say so, but they were probably made short by his request or his pencil. Science teachers are busy people; they do not have time to read long drawn-out discussions. The editor's and reader's ideal is an article that says much in a few words.

March, April, May, September, October, November, December of 1901 and January and February of 1902 form Volume I, a very remarkable volume for a beginner, consisting of 506 pages, plus the index and advertising. The first volume was so successful that before the close of the second year an advertisement was inserted calling for back issues of April, 1901, to complete sets of Volume I. This first volume contains material so important and valuable that almost the entire volume has recently been reprinted in order to supply the demand.

Volume III consists of 542 pages plus advertising, but here is the beginning of a separate section for Mathematics—the *Mathematical Supplement* of *School Science* appeared in April. Three issues of the Supplement appeared in 1903, April, June, and October, then the Supplement became a separate journal, *School Mathematics,* and appeared in two issues, January and March, 1904. The *Mathematical Supplement* was edited by George W. Myers with C. E. Linebarger as managing editor. *School Mathematics* was edited jointly by George W. Myers and C. E. Linebarger. The list of associate editors contains

among others some very famous names in mathematics: Robert J. Aley, Indiana University, C. E. Comstock, Bradley Polytechnic Institute, G. A. Miller, Stanford University, Charles W. Newhall, Shattuck School, Faribault, Minnesota, John C. Packard, High School, Brookline, Massachusetts, David Eugene Smith, Teachers College, Columbia University.

In 1904 only three isssues of *School Science* appeared, April, May, and June. *School Mathematics* did not appear again. In neither case was it due to a lack of interest. Both of the editors were research men and believed they could not give up their research interests in order to put out a journal, no matter how great its demand. Years later, when the present editor took over the work after the death of Charles E. Smith, Professor Myers, still the departmental editor for astronomy, said: "You will make a good editor if you forget any investigations you have planned and concentrate on your work for others." This choice of alternatives we have found to be indeed necessary.

The original *School Science* seems to have gone to sleep with the June issue 1904, and the *Mathematical Supplement* with the March issue 1904. The only excuse given was announced in the Program for the fourth meeting of the Central Association of Science and Mathematics Teachers. On the first page of this pamphlet we find: "The publication of *School Science* will be temporarily suspended; it will in all probability to resumed next January. This action has been taken not because of any lack of support from subscribers as well as contributors, but because of the inability of the editors to give at present the time and attention to the journal required for successful and regular issuance. Those whose subscriptions have not expired may at their option have the balance refunded or apply on subscription when the publication of the journal is resumed." This announcement indicates that practically all subscribers were members of the Association.

Four years had now been spent in trial. The men in charge during this time were scholars, and a journal was not their prime interest. Hence they could not give it the time necessary for successful operation.

The Journal Takes Its Permanent Form

In the latter part of 1904 two new men, Charles H. Smith and Charles M. Turton, both well known in the Chicago area, took over *School Science* and *School Mathematics* and welded them into one publication, *School Science and Mathematics*—not really a new journal, because all previous unexpired subscriptions to each of the two parts were honored. This uniting of the two publications was a recognition that in practical science there was a fundamental need of mathematics as a firm base and of the use which mathematics makes of the new discoveries and developments in other scientific fields for her future progress. A general recognition of this close relationship was made by the colleges in 1941 when the Cooperative Committee on Science Teaching was organized. In January, 1905, the first issue of *School Science and Mathematics* appeared under the editorship of Mr. Smith with Mr. Turton as business manager. The time of trial had now passed. Two men with determination, foresight, and boundless energy had been found. Volume V came through with nine issues, 779 pages of excellent material for teachers of mathematics and science. Previously *School Mathematics* had taken a very important step by recognizing the necessity of improving the mathematics teaching in the elementary school and now continued to give assistance to grade school mathematics. The other sciences were practically unknown in the elementary school and remained so for a number of years except in a few very progressive schools. High school botany, zoology, chemistry, and physics was largely preparation for college careers in science.

Mr. Smith and Mr. Turton saw the need for a national journal for science teachers. (The term science throughout the remainder of this chapter includes the basic science, mathematics.) To accomplish this, they attended science meetings in all the Central States, carrying with them on each trip an armful of past issues of the Journal which they passed out to science teachers. How fast the subscription list grew cannot now be told because no records are available. But we have the word of the late Mr. Turton that all his records were kept in a

little desk in the hall of his home, and that for about five years all income was spent in advertising and putting out the Journal. The work of both editor and business manager was contributed without financial remuneration. No outlay was made for office help; everything was done by these two teachers. But they were both practical business men and visionaries. They believed in the value of their product and were willing to work for it. Not only the Association but also the entire science teaching profession and their students are deeply indebted to these men for contributing so much time and energy for the benefit of science teachers and students in all future time. What a wonderful monument they built in their memory but without any such thought or aim! They allowed nothing to take their attention from the work of the Journal during all off-duty hours. Yet, in spite of this extra burden, both of these men were excellent physics teachers in the Chicago public schools.

Mr. Smith and Mr. Turton believed thoroughly that their mission as teachers could be greatly expanded by putting out a magazine primarily devoted to the teaching of science. But it is doubtful if they then believed that the Journal would attract the attention of the world and be read and followed by many of the most important teachers of all countries. Even today there are some who think the Journal is read only by a few teachers in the Central States. It is a revealing experience to visit the great educational libraries all over the country and see the bound copies of past issues of the Journal in daily use, or to look over some of the letters that come to the editor's desk from countries all over the world asking for reprints or copies of articles published back in the early years of the century. Even now letters come from behind the Iron Curtain asking for certain copies or for an exchange of journals. Many of these foreign journals the editor cannot read, but our Journal is sent so that they may see what and how we attempt to teach the boys and girls of this country, and thus make every American citizen able to hold a responsible place in time of peace or war, whether his place be that of leader or of follower.

Raising the Standard of Published Articles

Although the demand for the Journal was evident from the start, it was not always easy to get the type of material teachers wanted. Even the leading science educators of the country did not understand the needs or desires of teachers in the ranks, nor did they in many cases realize that they and their professional work would benefit by what was published in a small professional journal put out for the benefit of high school teachers. As one movement to overcome these errors and to get worthwhile material for teachers, Messrs. Smith and Turton were instrumental in organizing "The New Movement among Physics Teachers," started in the Physics Section of the Central Association of Science and Mathematics Teachers, December 2, 1905. This study extended through more than two years and attracted articles from such great men as President Nicholas Murray Butler of Columbia University, President G. Stanley Hall of Clark University, Prof. Albert A. Michelson of The University of Chicago, Prof. J. Mark Baldwin of Johns Hopkins University, Prof. George R. Twiss of Ohio State University, and others.

While this was taking place in physics, the departmental editors in other sections were not asleep. G. W. Myers of The University of Chicago was the first editor of the Department of Astronomy, starting with No. 1 of Vol. 1. In 1905, he added mathematics to his department but in less than two years' time the work in this subject had grown so rapidly in influence and importance in Journal affairs that Herbert E. Cobb of Lewis Institute was made a coordinating editor. Otis W. Caldwell, a young man from the Normal College at Charleston, Illinois, was selected in 1904 to edit the botany papers. In 1914, Frank Wade's name first appeared as editor for chemistry. Thus we might go on for many pages listing the names of great teachers who found time beyond their regular work to teach in distant lands and in future years students whom they never met, by inspiring them to do better teaching and by editing articles prepared for publication in this Journal. All these were leaders in

the various fields of scientific education. Many of these men continued their editorial work long after they had retired from active duty as teachers, some serving until death ended their teaching careers. Today the oldest in point of service is Professor B. Smith Hopkins, of the University of Illinois, who became editor for chemical research in 1917.

School Science and Mathematics has always been closely associated with the Central Association of Science and Mathematics Teachers, but for many years they operated as two separate educational agencies for the advancement of science. The Journal first appeared in March, 1901. About a year later, physics teachers from some Chicago schools and other cities near-by met in Chicago to discuss the organization of an association of physics teachers of the Central States. The result of this and later meetings is told in another part of this chapter. Mr. Charles H. Smith was one of the leaders in the organization of physics teachers and was its first president. Teachers of other sciences at once saw the advantages of a combined organization and the Central Association of Science and Mathematics Teachers was the result. Mr. Smith was twice elected president of the new association. It is now fifty years since the first issue of *School Science* came off the press, forty-nine years since the Central Association of Physics Teachers held its first meeting, and forty-eight years since the Central Association of Science and Mathematics Teachers was formed.

School Science and Mathematics has published all the reports of the Central Association submitted for publication, and it has encouraged organizations of science teachers in all parts of the United States, publishing announcements of their meetings and often papers presented there. For many years it has published reports of the Eastern Association of Physics Teachers and all of the members of this organization get the Journal regularly.

In the early twenties, general science began its work as a freshman high school subject. A few leading schools and cities had been working on this subject and trying it out in various forms for a number of years. Notable among these was the Laboratory School of The University of Chicago where a text was put out by Caldwell and Eikenberry, two members of the

Central Association, in 1917. John C. Hessler of James Millikin University, another member of Central Association, put out a text three years earlier. Ada L. Weckel, later a president of the Central Association, introduced the subject at Oak Park, Illinois, and was the author of one of the early books published in 1916. *School Science and Mathematics* had published a number of articles in this field and a special editor for this work was appointed in January, 1917. He was Fredric D. Barber of State Normal University, Normal, Illinois. Mr. Barber served until 1924 when Mr. Ira C. Davis of the University High School at Madison, Wisconsin, took over the work of this department and served as a successful editor for over eighteen years. In 1943 he transferred this work to Prof. Walter A. Thurber of New York State Teachers College, Cortland, New York, who is still in charge of this department.

When the elementary schools in many places began regular instruction in science, *School Science and Mathematics* was again called upon for aid, and another new department was formed with one of the leading men in the field in charge. Mr. Harry A. Carpenter of Rochester, New York, was selected and ably filled this place from April, 1929, until December, 1938, when it was taken over by Mr. David W. Russell of the National College of Education, Evanston, Illinois. Mr. Russell ably conducted this department until 1947 when he gave up the work to Miss Anna E. Burgess, Supervisor of Elementary Science of the Cleveland Public Schools. Thus the magazine sections devoted to Elementary Science and General Science have each had but three editors.

From the beginning, Mr. Myers had recognized the dependence of the high school mathematics on the previous work in the grades. The first issue of the *Mathematical Supplement,* April, 1903, contains an article for all mathematics teachers on "The Outlook for Arithmetic" by David Eugene Smith. Thus mathematics differs from the other sciences in respect of its recognized dependence on grade school teaching. Many of them first developed as college subjects and were later carried down into high schools and very much later into the grade school work. This process is still taking place and even today very few

schools have completed a full course in elementary science except in the mathematics. This Journal originated as a secondary schools journal but, before it attained its present form as *School Science and Mathematics*, it had already recognized its dependence on the work in the grades. However, not until April, 1929, was elementary science recognized as in need of the attention of a special editor. Part of this delay in recognition may have come because the Journal control recognized that to introduce a new department meant either a decrease in the space allotted to other departments or an increase in Journal size. In the opposite direction recognition of the relation of the high school to the college seems to have been accepted from the start. At that time the secondary school was almost entirely a preparation for college work, so it is easy to see why college teachers were interested in the work of the secondary schools. This interest has continued and is now recognized by the Central Association of Science and Mathematics Teachers by allotting time for a special program at each annual convention devoted to the interests of the junior college teachers.

The growth of the Journal was continuous from the beginning in 1901 to the First World War period. Then the curtain was drawn over central Europe for a time, and subscriptions and exchanges to war torn countries could not be sent abroad. But, as soon as the curtain was lifted, the exchange of journals was resumed. Science is a universal language; no great fact of science can be retained by one individual or by one people for a long time. But the effects of the war on both Europe and America can not be determined by a single glance. Consider just one item. Before the war all optical supplies used in America were imported from Europe. Look around at the apparatus in many of our older laboratories and you will find that the lenses and prisms were ground in central Europe. This source of supply was cut off from the United States by the war. Our government called for all the privately owned binoculars and field glasses in this country. A great committee composed of some of our best scientists from three of our greatest industries was formed to provide a more permanent solution to the problem. The result of their work was a complete success.

We then began making our own glass and have since produced some of the greatest optical instruments of all time and have provided our people with the best of instruments for study, work, or recreation, completely made in America.

Change of Editors

In the spring of 1926, *School Science and Mathematics* received its first heavy blow. For some years the editor, Mr. Charles H. Smith, had felt the effects of excessive activity—an excellent teacher in a great school, assistant principal at the same time, head of a great summer school, a leader of boys and young men in social and educational work, a great church worker, and participant in numerous other activities, all in addition to his position as editor of a science journal known and respected in all parts of the world. His labors broke his health; his death occurred May 18, 1926. The June issue of the Journal was proof-read and completed by the Business Manager, Mr. Charles M. Turton. A month later the Smith interest in the Journal was sold to Glen W. Warner and the October issue came out with Turton and Warner as publishers. Mr. Turton continued as business manager and Mr. Warner became editor with the complete list of associate editors continuing in charge of their respective departments. Along with this change it may be interesting to note a few minor changes that have taken place in the appearance of the Journal. The first issue, No. 1 of Vol. 1 for March, 1901 came out under the heading

Vol. I.] MARCH, 1901. [No. 1.

School Science

A Journal of Science Teaching in Secondary Schools.

EDITED BY C. E. LINEBARGER.

This was followed by a list of the Associate Editors with the subject represented by each and his school address. A part of the contents followed on the first cover page. This display was continued for the first four years but with the addition of mathematics in April, 1903. Three issues of the *Supplement* were published, in April, June, and October, 1903 under the title page:

Vol. I. APRIL, 1903 No. 1.

Mathematical Supplement

of

School Science

Managing Editor:
C. E. Linebarger.

Mathematical Editor:
George W. Myers.

Otherwise the *Supplement* was similar in form to *School Science*. But the following year the *Supplement* became a separate journal, No. 1 of Vol. 1 appearing in January, 1904.

Vol. 1] JANUARY, 1904 [No. 1

SCHOOL MATHEMATICS

A JOURNAL FOR MATHEMATICS TEACHERS

EDITORS
GEORGE W. MYERS C. E. LINEBARGER

Only two issues of this Journal were published, January and March of 1904. The following January, Smith and Turton had taken over both journals and the January issue came out as

Vol. V.] JANUARY, 1905 [No. 1

School Science and Mathematics

A Journal of Science and Mathematics Teaching in Secondary Schools

Founded by C. E. LINEBARGER

CHAS. H. SMITH, Editor CHAS. M. TURTON, Business Manager

Then followed a list of six department editors for biology, chemistry, earth science, mathematics, meteorology, physics, and a longer list of associate editors for the same subjects except that meteorology was omitted. One issue under this heading was all that was published. Perhaps the readers wrote to the editor and recommended simplification. The second issue of Vol. V came out with mathematics and science coordinated under the heading shown at the top of the next page. It displayed a much longer list of associate editors. It seems quite evident that the intention of the editor was to put mathematics on a par with science, because all through the January issue, mathematics is given a coordinate position with science. In October of the same year the name of the magazine was simplified to read as shown at the bottom of page 30 and remained so until January, 1928, when a new appearance in cover form took place. The principal change then made consisted of displaying a list of the principal articles on the cover

Vol. V. No. 2] FEBRUARY, 1905 [Whole No. 31

School Science and Mathematics

A Journal for Science and Mathematics Teachers in Secondary Schools

Founded by C. E. Linebarger

CHAS. H. SMITH, Editor
Hyde Park High School, Chicago

CHAS. M. TURTON, Business Manager
South Chicago High School, Chicago

page in place of the names of the departmental editors. One other important change has taken place; in response to the wishes of the Journal Committee and some members of the Board of Directors, a change in the appearance of the Journal was decided upon. A new design was submitted and adopted, and made its first appearance as the cover of the issue of April, 1940. The only wording on the front cover page now is the name of the Journal with the volume, number, whole number,

Vol. V. No. 7] OCTOBER, 1905 [Whole No. 36

SCHOOL SCIENCE AND MATHEMATICS

A Journal for Science and Mathematics Teachers in Secondary Schcols

Founded by C. E. Linebarger

CHAS. H. SMITH, Editor
Hyde Park High School, Chicago

CHAS. M. TURTON, Business Manager
South Chicago High School, Chicago

and the date of issue. The upper half of the inside cover page contains the essential statement of the classification and dates of publication, the price of subscription, and the copyright, followed by the names and addresses of the editor, business manager, and associate editors.

Central Association Buys The Journal

The firm of Turton and Warner continued for just two years when Mr. Turton retired from active duty as manager and the Journal was sold to The Central Association of Science and Mathematics Teachers, Inc., the money being provided by the sale of debentures to mature in ten years. The face value of the debentures was from $10 to $500, only one of the latter size being sold. The major part was raised by the sale of the ten-dollar debentures; many of those who thus supported the purchase did so with the feeling that they were making a contribution to the purchase rather than that they were investing in it. Mr. W. F. Roecker of Milwaukee was president of the Central Association when the purchase was made in the summer of 1928, but it was some months before the right man was found for the business manager's place in Journal affairs left vacant by the retirement of Mr. Turton. By the time of the annual meeting in November, Mr. Roecker himself was induced to take over this work. It soon became evident that the right man had been found to look after the financial affairs of the Journal. Within ten years, to the great surprise of many of the debenture holders, the debentures were paid in full except for a rather small amount owned by two members whose names were withheld at their request. These two made outright contributions to the Association. Both of these members were past presidents of the Association and continued to give the Association their earnest support, both in valuable time and in the purchase of the Journal. One of these, Professor Elliott R. Downing, was claimed by death in 1944.

After the sale of the Journal to the Association in the summer of 1928, at the request of the executive committee, Mr. Warner continued the work of editing until the meeting of the Board

of Directors at the annual meeting in November. So much work was to be done by the Board in selecting a business manager and looking after the financial affairs of the Journal and the Association that no time was left for selecting an editor. After the business meeting, Miss Ada L. Weckel, the new president, asked Mr. Warner to continue as editor until a new one could be found to replace him. To the present time, now twenty-two years later, he is still editor. From the time Mr. Roecker became the business manager in January, 1929, the Journal has been operating with ever increasing influence and benefit to the teaching of all the basic sciences and thus to education in general.

The purchase of the Journal by the Association was made just prior to the greatest financial break in our nation's history. Great financial structures tumbled the world over, but *School Science and Mathematics* was paying cash for all its printing and other expenses. More than this, it was laying aside money for the payment of debentures when they fell due. Before the end of the depression period and before business began to improve due to the great war in Europe, the debentures had been paid off completely and *School Science and Mathematics* was now truly owned by the Central Association of Science and Mathematics Teachers, Inc. One more major change in operation brings us to the present time. In the late summer of 1942, the Journal suffered the loss of its business manager, Mr. W. F. Roecker, who died on September 13 after a brief illness. His work was taken over by his wife, Mrs. Sylvia Roecker, who had been his able secretary all during his official service, and by the Treasurer of the Association, Mr. M. J. W. Phillips, who carried responsibility for Journal management until the end of the school year.

When the Board of Directors met in the spring of 1943, it had a difficult job to perform. A new business manager was to be found. Everyone was now in some manner doing extra work for the U.S.A. to bring the Second World War to a successful end. After a long discussion it was decided to intrust the work of the Journal to Capt. Ray C. Soliday, then in the uniform

of the United States Army but stationed at Chicago in the work of the Chemical Warfare Service. It was a risk to take, because no one in service can say where he will be the following day. But many jobs in the work of the Central Association of Science and Mathematics Teachers had previously been done by a "silent" partner. Some of the members of the Board of Directors knew Mrs. Soliday, hence Captain Soliday was selected as the Business Manager in the belief that he could carry the responsibility and his military duties with the help of Mrs. Soliday. All during the remainder of the war, Mrs. Soliday kept the work going even though the Captain did not get into his office for months at a time. At the annual meetings she is always at the registration desk and the work is well done. No mistake was made in the selection of Captain, later Major Ray Soliday. If he cannot be present to take care of the job, it will be correctly done by Mrs. Eleanor Soliday. So long as the Association can provide a business staff of this type, the work at home will be well taken care of. But this is not all that the business office has to do if the influence and value of the Journal are to be extended. The Journal started with a small group in and near Chicago. Through the work of the editor and business manager while attending science meetings and as a result of other organized activities, the membership grew and the influence and value of the Journal increased rapidly. All through the period of private ownership it was the regular custom of the owners to invest from one hundred to two or three hundred dollars per year in travel and hotel expenses in order to increase the subscription list of the Journal. At present rates, the outlay would need to be two or three times as great if done in the same way. But the rate of growth in the subscription list has now leveled off even though the number of teachers of science has greatly increased. Illinois has always had by far the greatest number of subscribers of any state in the Union. Part of this is of course due to the custom of holding the annual meeting in Chicago or in some city not at a great distance from Chicago. But the list of contributors to the Journal shows that it is equally useful in all other sections of the United States.

This situation poses a major problem of study for the Journal Committee and for the Board of Directors.

The members of the editorial board have changed frequently. Part of this change takes place because departmental editors become more interested in some other work they are doing and ask to be relieved. In some cases they have been asked to transfer their work to others who seemed capable of getting better results. Some years ago a very prominent teacher, who later became president of the Central Association, recommended that all departmental editors should change or be reappointed after three years of service. His idea, that no one should hold a place on the staff without giving high class, continuous service, is to be commended and followed if the editor and Journal Committee are to keep an active and efficient staff. Those who have remained on the staff for many years have given excellent service. This is done entirely as a contribution to science teaching. They give time and energy to improve the teaching of science. In many respects the departmental editor has a difficult job. He must judge the value of a paper to the readers, not only its own intrinsic worth. Its value may be immediate or it may be lasting. Frequent calls come to the business office for copies of articles published twenty-five, thirty, or more years ago. Entire issues of the early numbers of the Journal have recently been reproduced to supply the demand.

Nearly all editorial conferences must be carried on by mail. Our staff is now located from Boston to Wichita, but papers are frequently sent to college and university men all over the country for judgment and discussion of their value to the profession. This requires a considerable amount of time and work by scientists and educators whose names never appear on our list of editors. But it is such assistance that has helped the editorial staff to build up and maintain the reputation of the Journal.

Two or three special departments are worthy of attention. Our Problem Department has been a regular feature for many years. It is a section that attracts the attention of mathematicians of all caliber from high school students to university pro-

fessors. The editor of this department carries on a heavy correspondence, not only with students, teachers, and professors in this country, but in various cities of the globe. The list of contributors which he publishes regularly is but a small part of the total number who use his work. Another department, always appearing in small type near the end of each issue, attracts the attention of many who use it to keep their libraries up to date. All the leading book companies examine carefully the reviews of their books and often use quotations from the reviews in their advertising. Our reviewers must condense their comments because space is limited. They are asked to avoid personal opinion in any criticism made, but facts must be pointed out, no matter what the cause of the error, and now and then a book appears, even from a scientific press, which should never have been published. Our advertisers make the Journal possible in its present form, but whether they are book companies or apparatus supply houses, they want the truth told about their products.

Presidents and Places of Meeting
Central Association of
Science and Mathematics Teachers

Chicago, 1902, 1903, 1904
*Charles H. Smith, Hyde Park High School, Chicago

Chicago, 1905, 1906
*Otis W. Caldwell, State Normal School, Charleston, Illinois

St. Louis, 1907
*Clarence E. Comstock, Bradley Polytechnic Institute, Peoria

Chicago, 1908
*Franklin T. Jones, University School, Cleveland

Chicago, 1909–Cleveland, 1910
*James H. Smith, Austin High School, Chicago

Note. The institution named is that at time of election.
* Deceased.

Chicago, 1911—Evanston, 1912
*Herbert E. Cobb, Lewis Institute, Chicago

Chicago, 1913
*James F. Mills, Francis W. Parker School, Chicago

Chicago, 1914
Willis E. Tower, Englewood High School, Chicago

Chicago, 1915
*Chauncey E. Spicer, Joliet High School, Joliet

Chicago, 1916
Herbert R. Smith, Lake View High School, Chicago

Columbus, 1917
E. Marie Gugle, Columbus Schools, Columbus

Chicago, 1918
Harry D. Abells, Morgan Park Military Academy, Chicago

Chicago, 1919
Jerome C. Isenbarger, Senn High School, Chicago

Chicago, 1920
J. Albert Foberg, Crane Technical High School, Chicago

St. Louis, 1921
Walter W. Hart, University of Wisconsin, Madison

Chicago, 1922
Alfred Davis, Soldon High School, St. Louis

Indianapolis, 1923
Frank B. Wade, Shortridge High School, Indianapolis

Chicago, 1924
*Clarence Lee Holtzman, Waller High School, Chicago

Chicago, 1925
*Elliott R. Downing, University of Chicago

Chicago, 1926
*Frank E. Goodell, West High School, Des Moines

Detroit, 1927
Ernst R. Breslich, University of Chicago

Chicago, 1928
*William F. Roecker, Boys Technical High School, Milwaukee

Chicago, 1929
*Ada L. Weckel, Oak Park High School, Oak Park

Milwaukee, 1930
Walter G. Gingery, George Washington High School, Indianapolis

Chicago, 1931
Glen W. Warner, Crane Junior College, Chicago

Cleveland, 1932
Franklin R. Bemisderter, East Technical High School, Cleveland

Chicago, 1933
*Charles A. Stone, University of Chicago

Indianapolis, 1934—Chicago, 1935
Katharine Ulrich Isenbarger, Oak Park High School, Oak Park

St. Louis, 1936
O. D. Frank, University of Chicago

Cincinnati, 1937
W. R. Teeters, St. Louis Schools, St. Louis

Chicago, 1938
Ira C. Davis, University of Wisconsin, Madison

Chicago, 1939
Marie Sangernebo Wilcox, George Washington High School, Indianapolis

Cleveland, 1940
Nathan A. Neal, James Ford Rhodes High School, Cleveland

Chicago, 1941
Harold H. Metcalf, Oak Park High School, Oak Park

Chicago, 1942
Joel S. Georges, Wright Junior College, Chicago

Chicago, 1943
George K. Peterson, North High School, Sheboygan

Chicago, 1944
*Emil L. Massey, Detroit Schools, Detroit

Chicago, 1945
Walter H. Carnahan, Purdue University, Lafayette

Detroit, 1946
Arthur O. Baker, Cleveland Schools, Cleveland

Chicago, 1947
George E. Hawkins, Lyons Township Junior College, LaGrange

Indianapolis, 1948
John E. Potzger, Butler University, Indianapolis

Chicago, 1949
Charlotte L. Grant, Oak Park High School, Oak Park

Chicago, 1950
Paul L. Trump, University of Wisconsin, Madison (resigned)
Allen F. Meyer, Mackenzie High School, Detroit

Ernst R. Breslich

Mathematics

THE COURSES in algebra, geometry, and trigonometry had their beginnings in the American colleges in the first quarter of the eighteenth century. There they were offered as logical sciences and their development and organization were based upon the disciplinary point of view.

During the first half of the nineteenth century, these subjects were moved downward from the colleges into the growing high schools. The dominant aims of the teaching of mathematics in the secondary schools were twofold: the disciplinary objective, and the acquisition of useful knowledge. The mathematical curriculum aimed to serve the needs of a comparatively small portion of the population of high school age: the future teachers, ministers, lawyers, doctors, surveyors, astronomers, and engineers, and it was generally believed that the mental training derived from the study of mathematics was particularly valuable to this type of pupil.

The number of high school pupils increased rapidly, and by the end of the nineteenth century it had grown to half a million. Although this was still a rather select group of children, educators were becoming critical as to the courses offered by the schools. The disciplinary values of mathematics were being questioned and there was a demand for mathematics that would be more useful to the learner. The teaching emphasis on mechanical performance and memorization of rules and proofs was deplored. Objection was raised to the highly logical arrangement which placed definitions, rules, and axioms at the beginning of a course and which brought in a great deal of abstract material that tended to dampen the enthusiasm of

pupils. These and other criticisms had reached the stage where they needed the attention of teachers, and in 1894 the Committee of Ten[9] suggested ways of bringing about some improvement in the teaching of mathematics. It recommended a closer relation between the mathematics courses offered in the high schools and advocated that some instruction in geometry precede the course in demonstrative geometry. It was to be a course in "concrete" geometry offered near the close of the elementary school period, to be followed during the next two years by algebra and geometry offered in parallel courses. Some solid geometry also was to be included. These recommendations at this time were looked upon as a radical change from the traditional curriculum.

The influence of this report was apparent in the report of the Committee on College Entrance Requirements in 1899.[10] It was in favor of an early course in "concrete" geometry during one-half of the seventh grade, the other half being allotted to "introductory" algebra. Introduction to "formal" algebra and "demonstrative" geometry was to be given a place in the eighth grade. Formal algebra and demonstrative geometry were to be continued throughout the ninth and tenth grades.

The first decade of the century saw the beginnings of movements for improvement which have influenced the teaching of mathematics to the present day. The need for improvement was being recognized not only in America but in England, Germany, and France. In fact, in all civilized countries the leaders in the field were searching for new and better ways of organizing subject matter and for better methods of teaching it. However, the story of improvement in the teaching of mathematics during the first fifty years of this century is one of progress typically American.

In England, John Perry advocated steady emphasis on the practical uses of mathematics as found in mechanical drawing, physics, chemistry, and engineering, the teaching of the general principles of mathematics through experiments and concrete examples, the acceptance of many propositions in geome-

try without proof, or the deferment to a later time when logical proof could be established, and more extended use of graphical methods.

In France, J. Tannery advised that some of the objectionable proofs should be replaced by common sense discussions based upon models and that the time saved thereby be employed to teach the elements of analytic geometry and calculus.

The same ideas were emphasized by Felix Klein in Germany. He recommended that a closer correlation be established between the mathematical subjects by stressing the function concept and functional thinking.

Thus, at the turn of the century several movements were developing in the teaching of mathematics to provide a type of mathematics that would fit in an educational program which would prepare pupils not only for college work but also for the activities in which they would engage later as adults.

The Growth of Associations of Teachers of High School Mathematics and of Mathematical Publications

The recommendations of leaders, no matter how promising they are, are slow in coming into wide use. They need to be studied and discussed by groups of teachers who examine the details and make recommendations for adoption or rejection. To accelerate the best possible adoption of recommended proposals, it was necessary to form efficient teacher organizations. One of the very first of these organizations was the Central Association of Science and Mathematics Teachers. It assumed leadership at the turn of the century and for fifty years has had a nationwide influence on the teaching of mathematics. Many teachers have always taught both science and mathematics and therefore had an interest in both subjects and were acquainted with the problems of teaching both. Hence mathematics and science were always represented on the programs of the Association, in the general meetings and in the section meetings. Today the meetings provide programs for teachers of the elementary schools, junior high schools, senior high

schools, and junior colleges. Half of the members are teachers of mathematics and of one or more of the sciences, the present membership being above one thousand.

In spite of the efforts of the teachers of mathematics during the first two decades to bring about far-reaching improvements, adverse criticisms of the methods of teaching and the curriculum have continued. The process of bringing about improvement throughout the nation was slow and the need for a national organization of the leaders of mathematics was becoming apparent. In 1920 the National Council of Teachers of Mathematics was founded. The purpose was to promote interest in elementary and secondary school mathematics; to make a study of the problems arising in the teaching of these subjects and of criticisms raised; to accelerate the progress of new educational movements by promoting presentations and discussions by the leaders in the field; and to recommend effective methods of teaching and better selection and organization of instructional materials. National Council held its first meeting in Cleveland, Ohio, on February 24, 1920. Since then annual meetings have been held in February or March and also many winter and summer meetings have been held.

The programs have provided presentations and discussions relating to the teaching of mathematics in elementary and secondary schools and junior colleges, the preparation for teaching, in-service training, tests and evaluation, and teaching and learning aids. Membership in the National Council exceeds six thousand.

Also many local organizations have become affiliated with the Council. A report of 1948 listed seventy-three clubs and associations that had become affiliated. The Council has sponsored a number of committees and commissions to promote investigations for the improvement of the teaching of mathematics and for better appreciation of its values.

The Mathematical Association of America was organized to promote research and to work in the interest of mathematics taught in the universities. However, it has sponsored the cause of mathematics in the high schools in its publications and in its meetings. It made possible the work of a number of national

committees and commissions. Because of the confidence which the Association enjoys with teachers, administrators, and the various mathematical organizations, it has been instrumental in securing adoptions of much needed reforms in the teaching of mathematics in the secondary field.

Besides these national associations, mathematics teachers have formed associations in many states. Thus, the Association of Teachers of Mathematics in New Jersey held its ninetieth meeting in 1949. The Association of Teachers of Mathematics in New England and the Association of Teachers of Mathematics of the Middle States and Maryland were founded at about the same time as the Central Association of Science and Mathematics Teachers. Many other states formed mathematical associations. Many of the state educational associations have mathematical sections which meet each year.

In recent years, a trend has developed to organize institutes, conferences, and workshops for teachers of mathematics. They are exceedingly profitable and are attended in increasing numbers from year to year. Institutes have been held yearly since 1941 at Duke University. The programs are organized generally around a theme such as "Mathematics at Work." Speakers of note from education, business, industry, science, and engineering deliver lectures that are followed by discussions. Arrangements are made for study groups for the discussion of the problems of the teachers.

Institutes for teachers of mathematics of grades 1 to 12 have been sponsored by the departments of mathematics and education of the University of Wisconsin since 1948, and by the Association of Teachers of Mathematics in New England at Wellesley College in 1949 and 1950.

Workshops for the study of problems related to the class work of teachers who wish to improve their teaching and the mathematical programs of their schools have been offered at Ohio State University since 1945 and at the University of Illinois at Galesburg, Illinois, since 1947. Since 1947 such workshops have been held annually in Indiana at one or other of the two state universities.

Mathematical conferences are held annually at several educa-

tional institutions. For example, the University of Chicago has held annual conferences on the teaching of arithmetic since 1946. The general plan of these conferences is to have a limited number of papers followed by conference discussions. The topics related to the teaching of arithmetic in elementary schools and junior high schools deal with the training of teachers of arithmetic, measuring results, advances in methods of problem solving, and methods of teaching.

In numerous cities and counties throughout the country, teachers have formed mathematical associations and mathematics clubs. As a rule, meetings are held monthly. Speakers present topics on ways of improving teaching procedures, curriculums, tests and measurement of results, and on research in mathematical education. Usually these addresses are followed by discussions by the members of the group.

One of the major tasks of the mathematical organizations is to acquaint the teachers of mathematics, the administrators of the schools, and the general educators with the meanings and purposes of reform movements and to enlist their sympathetic cooperation in bringing these to realization. This calls for full discussions and convincing arguments. A large phase of this work must be taken over by bulletins, mathematical journals, and yearbooks published by the associations.

Magazines for Mathematics Teachers

To meet a professional need, the journal *School Science* included in 1903 a *Mathematical Supplement.* In 1905 *School Science* became the official journal of Central Association of Science and Mathematics Teachers and the name of the publication was changed to *School Science and Mathematics.* Thus was established the only magazine of its kind in the English language. As the name indicates, it was a journal for both science and mathematics teachers, devoting itself to the improvement of mathematical teaching by a closer correlation between these subjects. From the beginning its issues have presented for teachers of mathematics articles on methods of teaching, the curriculum, history of mathematics, the preparation of teachers,

reports of committees and new trends. It contains a "Problem Department" which proposes problems of varying degrees of difficulty for those who are interested, and publishes solutions sent in by readers. Another valuable feature is the "Book Reviews" of new textbooks on science and mathematics. For twenty years *School Science and Mathematics* carried alone the responsibility for publishing articles on the teaching of mathematics and of the sciences.

At the time the National Council of Teachers of Mathematics was founded, the Association of Mathematics Teachers of The Eastern States and Maryland was publishing four times a year a journal known as *The Mathematics Teacher.* This was made official journal of the National Council of Teachers of Mathematics and it made its first appearance as such in January 1921. Since then it has been devoted to the problem of improving the teaching of mathematics, has aided teachers in their work, and has greatly increased the influence of National Council. It would be difficult to name a problem relating to the teaching of mathematics which has not been discussed at some time in the pages of *The Mathematics Teacher.* Hence files of this magazine will always be one of the sources of material most helpful to teachers and will constitute a valuable source of information and inspiration.

Although devoted primarily to the interests of collegiate mathematics, *The American Mathematical Monthly* has published many articles of value and interest to teachers of secondary mathematics. It is the official journal of the Mathematical Association of America and was founded in 1894.

In 1926 the *National Mathematics Magazine* made its first appearance. It was published bi-monthly at the Louisiana State University. Its purpose was to promote scientific methods of thinking, and to publish papers of research quality representing all mathematical fields. Its major interest was in the teaching of college mathematics but it has devoted much space to articles aiming to help high school teachers to keep up to date and to advance in their subject. In 1947 the title of this magazine was changed to *Mathematics Magazine.*

Scripta Mathematica has been published quarterly by Yeshiva University, New York City, since 1934. Devoted to philosophy, history, and expository treatment of mathematics, it publishes much that is interesting and helpful to teachers of mathematics and to their students.

One of the most valuable contributions to the teaching of mathematics is the series of Yearbooks of the National Council. The first volume appeared in 1926. The yearbooks deal with the problems of the teacher, curriculum changes, reports of investigations, aids and equipment used in teaching, and many other important phases of the teaching of mathematics.

During the past three decades several associations have published yearly bulletins, such as the Bulletin of the Kansas Association of Teachers of Mathematics which has appeared yearly since 1926.

Important Committees and Commissions

Intensive studies and problems in the teaching of mathematics were made mostly by individuals. In time a large part of this burden was delegated to committees and commissions. At the turn of the century various proposals and movements for reform had been made in this country. Many of them were worldwide. The task for making a survey of the trends for changes in the curriculum and methods of teaching was too great for any individual or small group of individuals. Realization of the magnitude of the task led to the appointment of the International Commission on the Teaching of Mathematics. This commission made a study of the mathematics situation in a number of countries. The status of mathematics in the United States was presented in four bulletins published between 1911 and 1918 by the Office of Education, Washington, D.C. A study of tendencies for change in curriculum and methods was made by Committees II and III. Some of the changes indorsed by the Commission were: Omitting geometric proofs that are too obvious or too difficult; deferring difficult parts of algebra to a later period; avoiding unnecessarily complex manipulations in early algebra; taking more applications and uses of problems from sciences and prac-

tical life; attaching greater importance to the utilitarian possibilities of mathematics. Bulletin No. 12 on *Training of Teachers of Elementary and Secondary Schools* advocates better preparation of teachers of mathematics.

The Mathematical Association of America together with organizations of teachers of secondary school mathematics organized the National Committee on Mathematical Requirements. This was in 1916. The report of the committee[15] was published in 1923. The purpose of the report was to give support to the movement for reform in the teaching of mathematics. Essential features of the report can be summarized as follows:

1. The formulation of valid aims of instruction in mathematics.
2. A mathematical program for grades seven, eight, and nine comprising the fundamental notions of arithmetic, algebra, intuitive geometry, and an introduction to demonstrative geometry.
3. Five plans for distributing the topics to allow the teachers freedom to fit individual needs and conditions.
4. Four plans for grades ten, eleven, and twelve.
5. Some recommendations for elections: elementary statistics, mathematics of investment, shop mathematics, surveying, navigation, and descriptive or projective geometry.

The program of 1 to 4 is to be "required" of all pupils, and the committee, after a study of materials suitable for preparation for college work, concludes that "there is no conflict between the needs of those pupils who go to college and those who do not." At the same time the committee recognized the differences in conditions by recommending more than one plan for distribution of topics.

Following the report of the committee of 1923, the university professors of mathematics continued to take an active interest in the teaching of high school mathematics, and when in 1935 the Joint Commission was appointed we find that it was composed of seven university teachers and seven teachers interested mainly in secondary school mathematics. In 1940 the Joint Com-

mission made its report.[8] It emphasized the fact that it would be unwise to attempt to formulate a single pattern of instruction in mathematics. Accordingly it presented two plans, thus indicating its belief that some study of mathematics should be made part of the education of every pupil. The selection and arrangement of the materials of instruction was based upon "guiding principles" formulated by the Commission, and the curriculum was organized in terms of seven major subject fields, each being subdivided into five categories.

The discussion of the curriculum, however, is but a part of this important report. Its value is greatly increased by the discussions and recommendations of the chapters on general aims of education, general objectives for secondary education, the place of mathematics in education, the problems of retardation and acceleration, evaluation of the progress of pupils, and the education of teachers. In the appendix are treated such topics as mathematical needs, transfer of training, terms, symbols, and abbreviations, classroom equipment, and a topical outline for slow pupils.

Another important report was made in 1940 by a committee appointed by the Progressive Education Association.[5] The report did not present a detailed organization of a mathematical curriculum. Much space is devoted to discussion of concepts and understandings applied in problem solving, the nature of mathematics, the evaluation of student growth, the purposes of general education and the relation of mathematics to these purposes. If mathematics is to deserve a place in secondary education, the committee says, it must contribute to the four aspects of living: personal living, immediate personal social relationship, social civic relationship, and economic relationship.

The United States Office of Education in cooperation with the National Council of Teachers of Mathematics appointed the Committee on Pre-induction Courses in Mathematics.[12] This committee outlined two courses for pre-induction purposes: a special one-year course comprising arithmetic, informal geometry, and algebra; and a one-semester refresher course for pupils near graduation or induction who were not at that time studying mathematics.

In the same year the Committee on Essential Mathematics for Minimum Army Needs made a report of its findings.[11] This committee had collected materials through conferences with army officers and by observing the basic training process during the first thirteen weeks of the inductee's army life.

The last of the large committees to report was the Commission on Post-War Plans.[2] It was created by the Board of Directors of the National Council of teachers of Mathematics to plan a program for secondary school mathematics in the post-war period. The first report was preliminary, making five proposals: The schools should provide mathematical literacy to all who can possibly achieve it; different courses should be constructed to meet the needs of all pupils; new attention should be given to the problem of providing adequate education for the slow student; the sequential courses should be improved; and the teaching of arithmetic should be improved. In the second report, the Commission emphasizes the responsibility of the school (1) to provide mathematical training for future leaders, (2) to insure mathematical competence for the ordinary affairs of life. A double plan is recommended for grade nine.

The last reports are evidence that the committees were planning adequate mathematical preparation of pupils for post-war conditions. Valuable lessons had been learned from the conduct of pre-induction and special training courses. In the years preceding the war, a trend had developed to reduce or eliminate mathematical requirements and thereby discourage the study of mathematics in high schools. However, when war came the importance of mathematical training was immediately recognized. The armed forces and industries were searching for men and women with sufficient mathematical background.

The need for mathematical training in general education in the post-war world should not be disregarded. General education aims to prepare pupils for efficient participation in the activities of later adult life, and mathematics has much to contribute to that aim. Boys and girls expecting to become skilled workers in shops and industries will be handicapped without mathematics. School subjects are becoming increasingly mathematical. The recommendations of the Joint Commission, the

Progressive Education Committee, and the Post-War Plan Commission should be studied by the teachers and put into practice in the schools, and every pupil's education should provide some mathematical training.

The Function of Mathematics in Education

From the beginning of the American high school, mathematics claimed a place on the curriculum on the ground that the learner would be benefited by the study of the subject. The average pupil in those days came to school to prepare himself for college. However, with the increase in the high school population a trend developed to educate all pupils rather than the selected few. At the beginning of the century the population had increased to 500,000. Many pupils now took mathematics although not interested in the subject, and the need arose for a change to a curriculum more suitable to them, more attractive and more profitable.

This change was reflected in the report of the National Committee of 1923[15] which recommended that "the work of the ninth year should provide the best mathematical training which the pupils are capable of receiving in that year and which will be the most useful to them with little reference to future courses which they may or may not take." Thus, the committee stressed the utilitarian values of mathematics rather than the disciplinary values. Likewise the Joint Commission of 1940[14] comes to the conclusion that mathematics is important in general education because "the average citizen of today needs considerable mathematical knowledge in the activities and experiences of everyday life and because mathematics is a means of understanding important aspects of the world."

A similar view is held by the Commission on Post-War Plans[2] of 1944-45, which points to the need of "mathematical competence for the ordinary affairs of life as a part of a general education appropriate to the major fraction of the high school population."

Thus, throughout the present century the view has persisted that the citizen in general is dependent on mathematics and that the school should prepare him to meet this need.

However, the practical function of mathematics is not the only reason why the subject should be taught in the high school. The study of mathematics also contributes to the enjoyment of the learner. Attention was called to these values of mathematics by the Educational Policy Commission of 1938 which says that "there is need of developing an appreciation of the cultural values of mathematics." Previously the National Committee of 1923 had stated a list of cultural aims including: appreciation of beauty of geometric forms in nature, art and industry; ideals of perfection as to logical structure; precision of statement and thought, and of logical reasoning; appreciation of the power of mathematics, and the role that mathematics has played in the development of civilization, in particular in science, industry and philosophy. These are strong recommendations and unless in the future the teachers of mathematics give serious thought to them the pupils will be deprived of an enjoyment to which they are entitled.

Furthermore, there is considerable reading material available: Histories of Mathematics, written especially for pupils; such pamphlets as *The Story of Numbers, The Story of Weights and Measures, The Story of Our Calendar,* published by the American Council on Education, Washington, D.C., 1933.

Bell, Eric. *Men of Mathematics.* Simon and Schuster, New York, 1937.

Dantzig, Tobias. *Number, the Language of Science.* Macmillan Company, New York, 1939.

Hogben, Lancelot. *Mathematics for the Million.* Simon and Schuster, New York, 1933.

Logsdon, Mayme A. *A Mathematician Explains.* University of Chicago Press.

Smith, David Eugene, and Ginisburg, J. *Numbers and Numerals.* Bureau of Publications, Columbia University, New York.

The teachers of mathematics in the early high schools assumed that the mental training derived from mathematics carried over automatically to other situations, including non-mathematical situations. Thus, the pupils who acquired skill in rea-

soning in mathematics were supposed to be able to reason in any subject as well as in mathematics. The training in memory obtained in mathematics would be helpful in any situation where memory is used. However, in the early decades experiments to determine the amount of transfer found that transfer was not nearly as great as had been supposed. Many educators interpreted this to mean that transfer may be disregarded as a value of the teaching of mathematics. Later experiments, however, indicated this to be an extreme point of view.

It is a major function of the school to train pupils in exact thinking. The entire school program should therefore contribute to the improvement of the quality of the pupils' thinking. Mathematics is a way of thinking. It continually exhibits the processes of thinking in simple form, and the technique of thinking which it uses is the same as that employed in the social and economic problems encountered in everyday life. Here is an important function of mathematics in education. The subject can and should be taught so as to make transfer possible. Thus, pupils must be led to understand the underlying principles in performing algebraic processes. They must be trained in methods of solving problems of algebra rather than in solving specific problems. Reasoning power is not increased by "memorizing" the proofs in geometry. Judd says that the teaching must be such as to encourage generalization. The teachers are beginning to assume this responsibility. They are learning how this may be done.

The task of the teacher in helping the pupil obtain the values to be derived from the study of mathematics has become more and more difficult. In the early high schools the classes were fairly homogeneous. With the growth of the high school population came a corresponding increase in individual differences. In a normal group some pupils are backward and slow and others are keen. The two types possess markedly different characteristics. What may discourage the slow may be a challenge and stimulation to the bright. The slow needs detailed instructions and rules which bore the others and which they dislike. To reduce failures the slow pupils are receiving the major share of

attention while the bright may be allowed to drift along without much effort. It is being more and more realized that the gifted pupils who are to be the future leaders have been neglected, and that they do not acquire the disciplinary values of mathematics as they should.

Several plans have been used to find a remedy for this situation. One is ability grouping. Pupils in the superior groups may be expected not only to do more work but a higher quality of work, work that will challenge their capacity and develop their mental powers. Mathematics clubs in which membership depends upon high quality of work in the class room have much to contribute. In some schools superior pupils are encouraged to take up the intensive study of some project in which they are interested. The Joint Commission has presented a list of seven projects for pupils in geometry, seven for pupils in algebra, and two for pupils in trigonometry. The purpose of such projects is to deepen the pupils' insight in mathematics, to increase understanding, to enrich the course, and to train them in habits of thoroughness, all of which are disciplinary values of mathematics.

During the nineteenth century the major purposes of mathematical instruction had been the acquisition of mathematical information and the discipline of the learner's mental powers. At the end of the century the leaders in the field of mathematics had come to recognize the need for ways of vitalizing the subject to arouse greater interest of the pupil, to facilitate the learning of processes and principles, and to increase his understandings of these processes and principles.

During the years 1900-1902 John Perry of England delivered some lectures on the teaching of mathematics in which he recommended a number of improvements. One of these was to place steady emphasis on the uses of mathematics in other school subjects, such as physics, chemistry and engineering and thereby to make an appeal to the learner. The recommendation was received enthusiastically by the teachers of mathematics in the United States and was widely discussed for the purpose of putting it into practice.

The need for mathematics in other school subjects is an excellent motive for study. It supplies real problems which vitalize mathematics. It clarifies the pupils' understandings of the principles taught. Moreover, it teaches pupils how to use mathematics and thereby it tends to remove one of the major criticisms that pupils do not know how to use the mathematics they have been taught.

In putting the recommendations into wide practice a number of obstacles were encountered. Many applications were more difficult to understand than the mathematics they were to clarify. If the teachers spent too much time on applications they were cutting short the time allotted to mathematics. Some teachers would teach only as much mathematics as was necessary to solve the problems, thereby reducing mathematics to a tool subject. Nevertheless the movement which placed emphasis on the uses of mathematics in other school subjects has persisted. If properly administered it is as strong and important today as it was fifty years ago. In many schools, other departments cooperate with the teachers of mathematics by giving them lists of concepts, skills, principles and problems which pupils need at various levels. The mathematics department then tries to supply the knowledge they are expected to possess.

The realization that mastery of mathematical processes and principles could be facilitated through the uses of applications in other school subjects naturally led to the uses in out of school life. Applications that fall within the pupil's experiences and which he understands can be selected from the trades, shops and the activities of everyday life of the adult. They are usually referred to as practical applications. If carefully selected they create confidence in using mathematics by applying to them mathematical techniques, and they add to the understandings of mathematical principles. They are related to topics usually taught in arithmetic, algebra, geometry, and trigonometry. During the last three decades several committees have collected practical problems, a recent and extensive list being published in the *Seventeenth Yearbook*[13] of the National Council of Teachers of Mathematics. This is a reference book of direct applica-

tions for junior and senior high school pupils. The applications are listed according to topics usually treated in the various mathematical subjects which is a convenience to the teacher who wishes to use them in his courses.

Pupils of high school age are concerned about the choice of their future vocations. Because during the last decades the uses of mathematics have steadily multiplied, they need in increasing number a good mathematical preparation. Applications of mathematics in problems relating to vocational work are therefore of interest to a large group of pupils, girls as well as boys. They are also an excellent means of illustrating mathematical processes and of teaching pupils how to use mathematics in real situations. The vocational applications of mathematics that are of interest to high school pupils are those of the electrician, the sheet metal worker, the pattern maker, the draftsman and the tool maker. Lack of knowledge of the required mathematics only too often is a stumbling block to pupils having shown real mechanical ability in the schools' woodshop, machine shop and in the domestic sciences. A large amount of the findings of studies to determine the mathematics needed in the various vocations has found its way into the regular mathematics courses.

As the school population increased and the interests of the pupils declined, the teachers of mathematics realized that they must give more attention to the mathematics that functions in the affairs of everyday life. Hence during the second and third decades many studies examined the activities of adults and of the community to determine the social applications of mathematics. They were drawn from the social situations which pupils could observe and understand. As in the case of all applications they were used to arouse and maintain interest, to give meaning to the mathematical processes and to teach pupils to use mathematics when needed in problem situations. At the same time the pupils were made acquainted with important facts and problems of everyday living. This served to "enrich" the work of mathematics. The advantage of the social situations is that they connect mathematics and life.

Thus, applications of mathematics play a prominent role in teaching, have informational value, arouse interest, motivate class work, add to the understanding of the mathematical concepts and processes, and train pupils to use mathematics in solving problems. The danger lies in the use of applications that are not understood, and in overemphasis on applications to the neglect of mathematics.

Mathematics had much to contribute to the testing movement which began early in the century. The traditional class examinations were given mostly for the purpose of determining the grades of the pupils. They were not comprehensive because usually they were made by selecting at random a few typical examples. They tested memory and mechanical performances rather than understanding and ability to apply and to reason. They had little diagnostic value and were of no use in providing remedial measures. The new tests tried to eliminate the faults of the class examination.

The early tests measured achievement (because it is most easily tested), in manipulative skills and informations. The influence of this type of test was soon apparent in teaching. Speed was overemphasized, and pupils were drilled until they could make automatic responses to questions. However, during the years that followed great advances were made in the construction of tests and in the uses made of them. Here the contribution of mathematics to education has been exceedingly valuable. Some of the first results of the newer tests was that the teachers became aware of the great individual differences among the pupils in a given class and of the possibilities of improving their teaching technique. Tests were now being used for grouping pupils in sections formed on the basis of intelligence test data. Emphasis then shifted to diagnosis, suggesting remedial work with individuals and with groups.

The new tests were used in such research work as the study of errors for the purpose of suggesting improvement of instruction; comparison of the effectiveness of various methods of instruction; the study of the mental processes in learning; and the measurement of attainment of intangible objectives of teaching:

understanding of concepts, power to reason, ability to solve problems, clear thinking, interest, attitudes and habits of work and study.

The National Committee of 1923 listed the following uses of tests: testing power in algebra, arithmetic, and geometry; measuring, mathematical ability; taking inventory of pupils' knowledge; reorganizing courses; and educational and vocational guidance. In recent years the function of testing has been extended further by using tests in appraising the pupils' "progress" in the attainment of the objectives of mathematical education. The Joint Commission and the Committee on the Function of Mathematics in General Education each devotes a chapter of the report to this phase of testing. Each gives suggestions for improving it. The process of measuring pupil progress is termed evaluation. Thus, the teacher of mathematics must set up definite mathematical objectives of a course, select the best teaching procedures leading to the acquisition of these objectives and construct tests which give not only evidence of attainment by the pupil but also of the progress he makes as he studies a unit and the course. It must be evident that such a program of evaluation will suggest a great deal of improvement of the tests that are used.

The modern school is assuming more and more responsibility for pupils' guidance, and evaluation has become of further importance in making guidance intelligent. May pupils fail in mathematics because they are misplaced in the course. A slow pupil may be able to make satisfactory progress in a group of average ability but fail in an advanced class. A superior pupil who finds himself in a class of slow pupils may have little to do and develops poor habits of work and study. In a class of demonstrative geometry the pupils may differ widely in previous geometric experiences. Some will be bored because their ability is not challenged, while others find progress too rapid for assimilation. These losses may be diminished by proper guidance. Someone who is responsible for classifying pupils should keep on hand the results of inventory tests, a record of previous experiences and of the type of work done by each pupil in previ-

ous courses. For example, much needless repetition can be avoided in a course in demonstrative geometry if the teacher is in possession of information showing what concepts, principles and skills have been acquired by pupils who have studied geometry in the junior high school.

The problem of classifying pupils was simple as long as high schools offered just one mathematical program for all pupils: algebra, demonstrative geometry, solid geometry and trigonometry. As new courses were being developed for different groups of pupils guidance became necessary. With the lowering or elimination of mathematical requirements for graduation, many pupils did not take any mathematics only to discover this mistake later when they found that their deficiencies in the subject formed a serious handicap in the work they had chosen as adults. Frequently it is impossible and usually it is difficult to remove at such a time the deficiencies by further mathematical training.

Responsibility for this lack of preparation usually rests with the parents or the school administrator who assumed that the pupil will never have need for mathematics. It is now recognized that school administrators and others who advise pupils as to the courses they should take are responsible for the guidance of pupils. The Committee on the Function of Mathematics in Education recommends that testing and evaluation provide the basis for guidance. The counselor must gather the data for planning the educational program. He should have access to the pupil's scholastic record and know his interests and abilities. He should be familiar with the mathematics needed by trained workers, by men and women in various industries, vocations and professions. A chart showing how high school mathematics contributes to the pupil's career which was published in the *Mathematics Teacher* in February, 1949 will be of help. The guidance report of the Commission on Post-War Plans[7] will be of value to him and to the pupil. In fact, it is addressed to the pupil and a copy placed in his hands will be exceedingly helpful to him. It is even more helpful to the parents and friends who wish to advise him. The nature of the report is reflected in the following topics:

1. Mathematics for personal use, as in the home and everyday activities. This information may be supplemented by courses in consumers mathematics and business arithmetic.
2. Mathematics used by trained workers, as bookkeepers, clerical workers, craftsmen, farmers and nurses.
3. Mathematical preparation for college.
4. Mathematics for professional workers, as teachers of mathematics and science, statisticians, surveyors, engineers, accountants, and researches in medicine and science.
5. Mathematics important in industries.

Curriculum Trends

Traditionally the mathematical content was organized for teaching purposes into separate courses: arithmetic, algebra, geometry and trigonometry, each being studied to the exclusion of the others. During the first decade a movement was started to break down the traditional organization by correlating these subjects with each other. The arguments in favor of this movement were numerous. It was thought that a larger number of pupils would be more interested in mathematics when several subjects are taught together; that resourcefulness of the learner would be increased if in attacking problems he may choose methods from several subjects; that a psychological arrangement would be facilitated; that needless reviews and repetitions would be avoided; and that complexity would be increased gradually if the content of each subject be distributed over a longer time.

Another movement which developed simultaneously with the first aimed to correlate mathematics with other school subjects, such as physics, biology, shop work and drawing. In some schools, the mathematics and science departments agreed to have the mathematics department take over some experiments usually performed in the physics laboratory and to have them performed in the mathematics classes. Similar arrangements were made between mathematics and drawing and shopwork. The major obstacles in this movement were the lack of equip-

ment and the keeping of records of credits in science or shopwork for work done in the mathematics courses. Various terms have been used to designate courses in mathematics which tried to relate the mathematical subjects with each other and with other school subjects. The term General Mathematics has persisted to the present time. Today it designates a mathematics course which draws its topics from all branches, including instruction in arithmetic, algebra, geometry and trigonometry. The geometry is of the informal type, not demonstrative. Much emphasis is placed on graphical representation, the formula, the equation, and applications that appear in the many activities of everyday life. The trigonometry is numerical. The lively discussions relating to general mathematics in the recent meetings of the Central Association and the National Council show that the teachers are as interested in it today as ever.

During the first decade the teachers of mathematics were greatly concerned about problems that arose from the gap between elementary and high school mathematics. There was much discussion of more suitable programs for the last two years of the elementary school courses as teachers were trying to bring about a better articulation. The opportunity to do this came through the junior high school movement and by the middle of the second decade a variety of courses in junior high school mathematics was fairly well established. The National Committee of 1923 brought unity in these efforts by proposing a complete outline for grades 7, 8 and 9. Four plans were submitted with suggestions for arrangement of instructional materials selected from courses in arithmetic, algebra, geometry and trigonometry.

This work was further extended by the Joint Commission which presented outlines showing the distribution and organization of mathematics for each of the three grades. The arrangement was such as to make the work possible in grades seven and eight of school systems not having established junior high schools.

General mathematics fitted well into this program. It made possible a better psychological arrangement of subject matter. It allowed sufficient time to include more explanatory and de-

velopmental material to develop basic concepts and principles slowly. Mathematics was related to practical and social situations including those which people in general would use.

Proficiency in arithmetic is a major aim of junior high school mathematics and the arithmetical processes receive much attention. In algebra it aims to develop meanings of basic concepts, teach formulas, graphs and simple equations and develop ability to solve verbal problems with emphasis always on interest and usefulness. Geometry is informal, experimental, observational, gradually closing the gap between informal and demonstrative geometry. The use of the geometric instruments in constructions is taught. Numerical trigonometry is applied to problems in finding inaccessible distances.

The traditional courses were designed for a rather select group of pupils, mostly those who planned to continue their education in college. Hence, the type of mathematics taught in the high schools has been greatly influenced by the college entrance examinations. Experiments with new courses in the secondary schools were thereby made difficult and the criticisms of the college entrance examinations increased. Objections were raised to the over emphasis on skills in manipulative work and on the lack of questions which required ability to apply mathematics and which tested understandings. The National Committee of 1923 therefore made suggestions for improvement:

1. Algebraic technique should be a means to an end and not an end in itself.
2. Skills beyond needs of applications should be required sparingly.
3. There should be some questions to test understandings of principles and ability to apply them.
4. Questions in geometry should test ability to draw valid conclusions rather than to reproduce arguments from memory.

In 1935, a commission of the college entrance examination board changed the type of examinations in mathematics. It now proposed to test understanding and appreciation as well as skills and information. Three types of examinations were proposed:

(α) An examination for those who wished to be admitted to college because of the work done in mathematics in the high schools.

(β) An examination for those who studied the minimum requirements in mathematics.

(γ) An examination for those who expect to do more advanced undergraduate work in mathematics and science.

In 1941, the College Entrance Examination Board added to the Mathematics Attainment Test an examination chiefly concerned with the concepts and techniques of arithmetic and algebra.[1]

As the high school population increased the college preparatory group became relatively smaller than that composed of pupils not interested in the traditional courses. As this was being realized, a variety of new courses developed for those who had special interests: shop mathematics, consumers mathematics, and social mathematics. However, this left a large group still unaccounted for, those who had no special interests but needed mathematical training.

Thus gradually a trend developed away from a single mathematical curriculum to provide for the great differences of pupils in interests and abilities. The Second Report of the Commission on Post-War Plans recommended a double plan curriculum which has come to be known as the double track plan. Objection has been raised to the term "track" because it may be interpreted erroneously to mean that the two plans have no relation to each other.

One of the plans retains the traditional sequence of courses. It is for those who are capable, interested and in need of a thorough mathematical training. Further improvement and development of this sequence is most pressing. Some carefully planned instruction in arithmetic should be provided in it. A larger contribution is to be made to training in citizenship. They should deal more effectively with the quantitative problems of the community and the nation and teach much that has informational value. This mathematical sequence, however, is of greatest importance because it is planned for the group from which are to come the future engineers, scientists and research

workers. The majority of pupils in this group expect to continue their education in college. To it also belong the mathematically minded who derive pleasure from the study of mathematics.

The second plan is intended for those who are not taking the traditional sequence or any of the special courses. It is a course in general mathematics. The organization of the content is to be more psychological and the mathematical subjects are to be correlated rather than presented separately each to the exclusion of all others. Moreover, provision is to be made for transferring to the first plan those from the second who become interested and find that they are able to do the work.

While much attention has been given to the development of mathematics courses important in general education, pupils having special interests have not been overlooked. For example, mathematics has an important function in "consumers education." There exists an abundance of problems in arithmetic, algebra, and geometry of value not only because they give mathematical training but because they develop intelligence in buying and selling food and clothing, in providing shelter, in investments and taxation. The Consumers Education Study[16] presents in detail the contributions that can be made during the elementary, junior and senior high school periods. It is a recommendation of the committee that consumer mathematics be taught by teachers of mathematics rather than incidentally by teachers of other subjects.

Another basis for determining the content of the curriculum is social usefulness. In the socialized high school program all subjects may be combined to make a single curriculum. Topics like triangles, factoring, equations, etc., are abandoned in socialized mathematics and are replaced by such topics as earning a living, budgets of family income, installment buying, etc. The objections of teachers of mathematics to this type of organization are that too much time is being spent on clarifying the life situations resulting in a neglect of mathematics and that the mathematics involved in the social situations does not include all the mathematics that should be taught.

As far back as 1917, Professor D. E. Smith advocated a course

in vocational mathematics. Such courses have been designed especially for those who are interested in vocational work: the future accountants, machinists, electricians, tool makers, metal workers and plumbers. There is a body of mathematical skills and knowledge that is common to all vocations and can be taught by the department of mathematics without any direct reference to a particular vocation, but of the mathematics needed in the various vocations is administered through the vocational courses the content would differ for different vocations.

Teachers of mathematics have always cooperated in educational movements and policies aiming to improve the product of our schools. They have long recognized the value of the uses of projects and activities that are helpful in the teaching of their subject. They enrich the subject, motivate its study and add to understandings. The activity program aims to accomplish these results. It makes use of activities in which pupils are genuinely interested and in which they like to engage. It draws its instructional materials from all subjects as they are called for in the activities. The importance of mathematics in such a program is recognized.

Serious objections to the program have been raised by teachers of mathematics who have given it a trial. They find that too many activities distract from the real purpose, the teaching and learning of mathematics. There is danger that this is left more or less to chance. The plan does not allow sufficient time for practice and development of understandings. The arrangement of content is not psychological. Mathematics is reduced to a tool subject and the great values to be derived by the pupil are lost. Activities will motivate but there must be direct instruction in mathematics and additional time for study. The disadvantages of the program outweigh its advantages.

The core curriculum designates a movement of building a curriculum around a few subjects fundamental to the education of all pupils. For example, the "core" could consist of the subjects of English, science, and the social studies. Mathematics is an essential subject in such a plan. In some schools the mathe-

matics needed in the study of the topics in the core curriculum are taught "incidentally." In others the mathematics courses are retained and the teachers of the core courses report deficiencies to the mathematics teachers who lend assistance in trying to remove them.

The question arises as to whether mathematics can be learned effectively by such a plan if mathematics is to be taught as a "system of understandings of concepts, principles, and processes." No doubt the social subjects can be taught interestingly without using mathematics and there have been schools whose science courses were demathematized. The same objections have been raised against the core curriculum that were listed previously in the discussion of the activity program. It is doubtful whether in the core curriculum the pupil can learn mathematics so as to be able to use it in new and unfamiliar situations.

During the past fifty years, far-reaching changes have taken place in the mathematical curriculum of the high school. Arithmetic was traditionally an elementary school subject. Hence, high school teachers were not concerned with the teaching of arithmetic and knew little about the problems and difficulties of the elementary school teachers. They complained about the poor preparation of the elementary school graduates, but no provision was made for the teaching of arithmetic in the high school.

Because arithmetic was used in subjects other than mathematics, dissatisfaction among the high school teachers grew and gradually it was recognized that not only the teachers of mathematics but the school itself should assume responsibility for the pupils' arithmetic. Many schools went as far as to offer a high school course in the subject. Numerous investigations were made to determine the typical arithmetical errors and difficulties and to find ways of overcoming them. The evidence made it clear that the study of arithmetic must be continued in the high school. Unless pupils have frequent occasion to use them, fundamental skills will be lost. Also, certain types of arithmetic could be presented more profitably in the high school than earlier, as for example, investments, insurance, taxa-

tion, and simple statistics. Emphasis will be on social usefulness, understanding, problem solving as well as on mastery of the fundamental operations. Moreover, high school teachers of mathematics should be men and women who had adequate training in teaching arithmetic.

The National Committee of 1927 recommended some instruction in arithmetic for every grade, to review and extend the concepts of arithmetic, to develop an understanding of the number system, to stress facility in computation, and to make use of the many opportunities for training in evaluation of formulas, solution of equations, checking and solving problems.

The National Council authorized the appointment of a committee on arithmetic in 1937 to study and report trends in the curriculum and the teaching of arithmetic, and in 1942 the subject of the Yearbook was *Arithmetic in General Education*,[17] a redirection of arithmetic instruction toward a meaningful comprehension on the part of the pupil from his early years through the high school. If the high school of today aims to prepare pupils to meet the quantitative situations of adult life every graduate should have attained proficiency in arithmetic.

Since the turn of the century, far-reaching changes have been made in the content and organization of the traditional courses. Before that time the major objective of algebra was facility in manipulating algebraic symbols and expressions. This was believed to be the type of work which best prepared pupils for the study of college algebra. Much time was spent in solving abstract equations and meaningless uninteresting problems. The arrangement of content was strictly logical, beginning with lists of definitions of concepts and axioms to be memorized and to be used later in the fundamental processes and equations. The pupil passed from topic to topic without seeing the connection between them. Each topic was developed "completely" to the exclusion of all others.

Changes came because of the changing objectives of education and of mathematics. Emphasis shifted to a type of algebra that people in general have use for and that could be made interesting to the learner. Moreover, the simple types of the vari-

ous mathematical subjects were being moved downward and the more difficult types of algebra were being deferred to a later period.

Unnecessarily complex manipulations in the early stages of modern algebra are now being avoided, while some of the simple aspects are being taught in the seventh and eighth grades. Here the meanings of many of the basic concepts are developed along with formulas and equations that are simple and useful. Geometry is used to illustrate and clarify the fundamental processes. Algebra is being related to life situations and much attention is given to actual needs. Hence the formula has become more important. Formulas illustrate relationships, teach pupils how to use algebra, and offer opportunity for preserving arithmetic skills in evaluation of formulas and solution of equations.

Verbal problems occupy a prominent place in algebra. They are formed in almost every topic. As far as possible they are real and are taken from other school subjects and from practical life. Emphasis is more on developing "problem solving ability" than merely on finding the answers. Attention is given to training in selecting data, understanding the mathematical and social situations, planning methods of solution, choosing the processes to be employed, recognizing and formulating relationships, and other phases of the technique of solving problems.

Formerly the study of graphs was deferred to college mathematics. Today it is an essential part of secondary school mathematics, and some graphical work is found even in the junior high schools. All types of graphs are used: picture graphs, bar graphs, line graphs, and graphs of precise mathematical relationships. They illustrate numerical data, formulas, solutions of equations, trigonometric functions. They picture functional relationships and are valuable in training in functional thinking. The Joint Commission recommended some work in graphs for every year of the mathematical curriculum.

Applications of statistics are found in almost every vocation or profession and every pupil should be acquainted with the elementary statistical procedures. The Committee on the Func-

tions of Mathematics in General Education expresses the belief that "the scope of statistics as treated in the secondary schools may well be extended" and that the student should thoroughly be acquainted with such terms as "measures of central tendency, measures of dispersion, associated variables, trend, and correlation." Slowly some of these topics are finding their way into textbooks on algebra, introducing such terms as the arithmetic mean, median, mode, the geometric mean, range, and trend.

Another topic which is finding its way into high school algebra is numerical trigonometry. The simple phases of trigonometry can be readily understood by a pupil who knows arithmetic and some informal algebra and geometry. It makes possible the introduction of applications that are interesting and useful. When the pupil has discovered that direct measurement is not always possible, that surveyors and engineers use other more accurate and more powerful methods, he is ready for a study of the methods of indirect measurement. The inclusion of numerical trigonometry in algebra was recommended by the National Committee of 1923 and many authors of textbooks have introduced a brief treatment of the subject in their courses.

When geometry became a subject on the high school curriculum, it was kept there largely because of its supposed disciplinary values. Because the major part of the teaching and studying was concerned with logical proofs, it was assumed that it trained pupils in power of reasoning which would transfer automatically to non-geometric situations where reasoning was employed. At the turn of the century educators began to question the disciplinary values of all high school subjects, and the findings of investigations which were carried on to determine the amount of transfer seemed to indicate that little or no transfer existed. Hence, greater importance was to be attached to the utilitarian values of geometry.

It was realized that during the elementary school period pupils acquired a considerable amount of useful geometric information in school and out of school. Teachers now attacked

the task of systematizing this body of information for purposes of instruction.

The National Committee of Fifteen on Geometry Syllabus appointed by the National Education Association[3] recommended that more time and opportunity be offered for the study of geometry in concrete relations and for concrete exercises, that some terms be accepted as undefined, and that some informal proofs should be accepted. Gradually during the second decades an informal type of geometry was being developed. While formerly only unmarked straightedge and compasses were permitted in constructions, use was now permitted of marked ruler, protractor, T-square, and squared paper. The usefulness of geometry was brought out constantly. Applications were chosen from three-dimensional geometry as well as from plane geometry. Geometry was correlated with arithmetic and algebra. The inductive approach was used in establishing new principles and meanings of concepts. The methods of observations and experimentation were employed to clarify meanings of many geometric theorems formerly proved deductively in demonstrative geometry.

The informal type of geometry became the geometry of the new junior high schools. It now was possible to give some systematized geometric instruction to all pupils as an introduction to demonstrative geometry. The National Committee of 1923, after listing the topics of informal geometry for grades seven, eight, and nine, states: "Before the end of this intuitive work, the pupil should have definitely begun to make inferences and to draw valid conclusions from the relations discovered." Thus the informal geometry could "make a gradual approach to, and provide a foundation for the subsequent work in demonstrative geometry."

Moreover, inductive, observational, and experimental geometry has formed a place in demonstrative geometry where it is being used to check conclusions against diagrams, to establish meanings of concepts, and to make clear the meanings of many theorems before deductive proofs are given. The National

Committee of 1923 gives a list of sixteen theorems of the type of propositions "which may be assumed or treated informally." This marks a radical change from the earlier demonstrative geometry. It is also the position taken by the Joint Commission which recommends a good course in informal geometry preceding the geometry of the tenth grade.

The informal treatment of some propositions in demonstrative geometry makes possible a reduction of the number of deductive proofs, especially of those that are too obvious or too difficult. A list of propositions to be proved is presented in the report of the National Committee of 1923. This list reduces considerably the number of propositions listed earlier by the Committee of Fifteen.

Many efforts have been made to treat the incommensurable cases of proportions in an elementary way. The results have not been satisfactory and the Committee of Fifteen recommended the exclusion of limits and incommensurable cases. The same recommendation was made by the National Committee of 1923. On the other hand, more attention was recommended to applications that are useful and related to environment and life situations.

More use is to be made of principles of plane geometry in three-dimensional geometry and some of the theorems of solid geometry analogous to those of two dimensions are to be introduced and proved in plane geometry. Emphasis or relationships between the parts of geometric figures and on functional thinking are to be made an important phase of instruction.

Training in reasoning in modern geometry is not incidental. The objective is to improve the pupils' skill in reasoning, to teach him the meaning of logical demonstration, to study the reasoning processes exhibited so concretely in geometry, and to employ them in non-geometric situations. Geometry is presented not merely as a collection of theorems and exercises but as a concrete illustration of a general logical system.

Fawcett's study of ways of teaching pupils the meaning of the nature of proof as reported in the *Thirteenth Yearbook*[18]

is an excellent discussion of classroom procedures aiming to attain this objective.

Methods of Mathematical Instruction

In the activity program and in the core curriculum mathematics enters "incidentally." Many educators regard this as an ideal method of teaching and learning in schools because a great deal of learning in everyday life is incidental. The incidental method introduces new mathematical topics as need for them arises in class work. The topics are thereby motivated, interest is aroused, and it is approached by the pupil with a favorable attitude.

By the end of the second decade the incidental learning method had attained the favor of many educators and for years it continued to gain in popularity. However, when teachers attempt to develop incidentally an entire subject, like mathematics, it was found that the method fails. It does not present mathematics as a science, the order of topics is not of gradual increasing difficulty, and the pupil is left with a distorted conception of the meaning of mathematics.

The method is effective if properly restricted: Thus, a topic may be introduced with a problem of interest to the pupil. Then during the solution the pupil finds that his knowledge of mathematics is not sufficient. Hence the new topic needs to be taken up for study. Later he returns to the problem and solves it. To the pupil, the mathematics seems incidental although it was planned for carefully by the teacher.

In 1902, a lecture given by Professor E. H. Moore of the University of Chicago called attention to the fact that assurance must come from understandings and that understandings should be derived by basing the development of new ideas upon understandings previously attained. This was the beginning of the movement for concrete mathematics which developed in the next twenty years. Today it is the rather general practice of teachers to derive the characteristics of new concepts and the meanings of new principles through the concrete experiences of the pupils. The concrete background clarifies

meanings and aids retention. Thus, if the pupil understands the fundamental processes with fractions in arithmetic, this knowledge may be used to aid in understanding the corresponding processes in algebra. Visual and manual aids are used to make clear the meanings of general number, signed number, and exponent, and graphs are used to clarify the meaning of "solution" of simultaneous and quadratic equations.

In geometry, such concepts as length, angle, circle, congruence, similarity, area, and volume are clarified by the use of ruler, sticks, blackboard compasses, cardboard, and squared paper. Concrete geometry lays the foundation for clear thinking and assurance.

In his paper in which Professor Moore recommends concrete mathematics, he also says that a constructive program for mathematics requires the development of a laboratory system of instruction. The laboratory method is a method of discovery. The classroom atmosphere is one of exploration rather than direction. The pupil observes, compares, draws, measures, and classifies. He formulates his own definitions and states new principles in his own words. For example, he draws and cuts from paper a triangle, cuts off the three angles, places them adjacent to each other and observes that the sum of the three angles is a straight angle. The advocates of the laboratory method claim that concepts and principles derived by it are understood, that the pupil uses them intelligently in applications, and that confusion is eliminated.

A number of schools followed Professor Moore's advice and established mathematical laboratories. Some enthusiasts predicted that the time would come when such laboratories would be as plentiful in mathematics as those in physics. This has not happened for several reasons. The laboratory method is difficult to use. A successful laboratory course in mathematics requires expensive equipment. The pupils have to be supplied with copies of guide sheets containing assignments, suggestions for study, and objectives. The busy teacher cannot find the time to prepare for laboratory work. However, good teachers of mathematics use the technique of laboratory method with good re-

sults in situations where it is more effective than other methods.

The major purpose of the laboratory procedure is to have the pupil learn by doing. To accomplish this a certain amount of equipment is essential. Some classrooms contain little more than a few pieces of crayon, some twine, and a few yardsticks, but even those can be helpful. Squared blackboards, blackboard protractors, blackboard compasses, models made by the pupils, and other homemade instruments are all important and helpful. The *Eighteenth Yearbook*[6] gives broad information about visual aids in teaching mathematics, including discussions of models and devices, instruments and tools, slides, films, and other equipment. Within the last five years a number of companies have produced mathematical movies, film strips, slides, radio programs and phonograph records for classroom use. The list is constantly growing and new films are usually reported and described in the issues of the *Mathematics Teacher*. The Committee of Evaluation of Films and Filmstrips promises to be of much help to the teacher.[4] It undertakes to find, list, and review worthy motion pictures and filmstrips in teaching mathematics. The reviews are published with specific suggestions as to their uses by the teacher.

To make the study of mathematics purposeful, it may be closely related to some project which is of interest to individuals or to a group of pupils. An example taken from arithmetic is the project of distributing the family's income. Another example taken from high high school mathematics and the shop work of the pupils is the building of a bicycle shed. Projects are usually formulated in the course of the class work. The mathematics involved in the projects suggest the topics to be studied. The project method like the laboratory method can be made very effective but becomes complex when carried too far. The criticism has often been made that the work done by the pupils is more project work than study of mathematics.

Yet, the value of a project should not be underestimated. Superior pupils often become interested in a project of their own and carry it on in addition to the regular class work under the

guidance of the teacher. Typical projects of this type are the uses of mathematics in sports, in music, in architecture, in machine work, in carpentry, in art, in nature, in jewelry, and in advertising.

Instruction in high school mathematics has been influenced by the practices in elementary school arithmetic. It was felt that in algebra, since, like arithmetic, it is dealing with number, the methods established for arithmetic should be suitable. In arithmetic the "drill method" was popular. It was based upon the theory that pupils learn best by frequent repetitions. Likewise, in geometry it was thought that pupils should be made to repeat definitions and principles until they were well memorized and to repeat proofs over and over until they could reproduce them fluently either in reciting or on paper.

The developing testing movement further tended to encourage the drill method because the early tests emphasized information, manipulative skills, and speed. Speed had become almost as important as accuracy. Pupils performed without understanding such mechanical processes as cancellation, transposition, removal of parentheses, and others.

Gradually the faults of the drill method were being realized because pupils did not retain a large amount of the memorized material. Slowly the teachers of mathematics turned to other methods. Drill has not been discarded. It renders an important service after understandings have been attained. This is the essence of the meaning theory. The drill theory assumed that learning would come from memorizing facts and principles. According to the meaning theory, learning is the result of a carefully planned study of concepts, principles, and processes. It has taken a long time to recognize the importance of meanings in learning. When the teacher has committed himself to that theory his next problem is to learn the methods by which meanings may be taught. The third step will be to develop tests to show the extent to which meanings have been attained by the pupils and to determine whether the pupil who has acquired understandings is able to transfer principles and techniques to new situations, that is, to use the mathematics taught.

The solution of these problems will require much research in the years to come.

The importance of meanings was recognized long ago by leaders in the field of high school mathematics. Algebra and geometry are full of abstractions which the beginner understands with difficulty. The prevailing practice in the early schools was to define a new concept or to state a new principle, supplementing the statement with a brief explanation, and then to have the pupil memorize the definition or principle. Acceptance of the principle was based mainly on the authority of the teacher. The method tended to undermine the confidence of the learner and to result in confusion as he continued in the study.

The foregoing brief review of methods of instruction discloses great progress in the teaching of mathematics during the past fifty years. At the beginning of that period the predominant method was to assign lessons and to hear recitations. The teacher of mathematics today is master of many methods. For each lesson he chooses the one that is most suitable. He no longer is merely a drillmaster, but aims to develop meanings which lead to the understandings of the concepts, processes, and principles to be learned by the pupils.

Outlook for Mathematics

An anniversary is a good time to look back into the past. Fifty years ago anyone with a college degree and a major in mathematics was considered qualified to teach the subject. He knew little about the problems of the classroom. He learned by the slow and expensive method of trial and error. Hearing lessons was the predominant classroom procedure. The class examination was not comprehensive, had no diagnostic value, and served merely as a crude method of determining marks. Very little was known about individual differences and a single curriculum aimed to serve the needs of all pupils. The teachers were not organized and there were but few publications to help them to improve. In all of these matters there has been steady progress and achievement. Indeed, some of these problems have

been solved in a satisfactory way. Today there is agreement as to the requirements for teaching high school mathematics. There has been a definite trend away from the single curriculum to provide for the great differences of pupils in ability and needs. The teacher of high school mathematics, the college instructors, and the general educator have learned to work together on educational problems.

An anniversary is also a good time to look ahead into the future. The school organization is constantly undergoing changes which call for corresponding changes in the school subjects. Problems arise that demand careful consideration and early solutions. New proposals must be given impartial trials.

The important role of mathematics in education has not always been recognized and often it has been denied. The lessons to be learned from the neglect of mathematical training have been valuable and should never be lost sight of in the future. General education aims to prepare pupils for efficient participation in the activities in which they must engage later in life. They must be taught to think independently and logically. Mathematics must make a contribution to this aim. Many have made claims that mathematics can be so taught as to do this better than most school subjects. The time for claims that are not yet substantiated by research has passed. Some beginnings have been made to secure this evidence but a great deal of research will have to be done to solve the problem.

The many new technological advancements and the growing complexity in modern industry will require a correspondingly larger number of boys and girls with mathematical training. This raises a problem that calls for increasing attention. An excellent beginning has been made by the Guidance Committee,[7] but work of this type will have to be continued.

The individual differences among pupils are now well known and much has been done to make provision for these differences. Classes are formed for slow pupils. Remedial instruction is offered. Multiple curriculum plans have been constructed. The slow pupil has received the major attention in all these plans and should continue to hold that attention. The superior

pupil, however, has been sadly neglected because he can take care of himself without special assistance. The problem of the superior pupil must be given more consideration. No time and effort has been spared to assist the slow. It will likewise require time and effort to provide properly for the bright pupils.

One reason why pupils do not succeed in mathematics is that they cultivate mental habits that are not only inadequate but positively harmful. Great progress has been made in the construction of tests that disclose the results of such habits as reflected in typical errors. Remedial work can then be planned to correct such errors. More should be known about the mental processes by which pupils arrive at faulty results. This information in turn should lead to methods of teaching correct mental processes which lead to correct results and by which pupils arrive at those forms of thinking which are characteristic of the trained student of mathematics.

The recent recognition of the importance of meanings in learning has emphasized the need for further development of tests to measure pupils' growth in the acquisition of meanings and of power. There is need for such tests to measure abilities to use mathematics in new situations, to solve problems, to reason logically, and to attain understandings of principles and processes.

Fifty years ago new theories of teaching and learning found acceptance largely because they were sponsored by some leaders in mathematics or education. Today the claims of new methods of teaching and organization are tested by research, and decisions are arrived at from the findings of investigations. Research will accelerate the slow progress of bringing about improvement.

The beginning of the second half of the century finds the teachers of mathematics well trained and organized. Teacher associations are ready to support new ideas and developments. Journals and yearbooks enlighten the teachers with discussions. Support is given by university instructors and school administrators. Speedy adoption of progressive recommendations is essential and, with an organization as it now exists, practice

should not be far behind the recommendations. The problem of securing nationwide adoptions of new recommendations is one of the most urgent tasks before the teachers of mathematics.

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The Biological Sciences

". . . When a teacher thinks chiefly of his subject, he teaches a science; when he thinks chiefly of his pupils, he teaches nature-study."

—Liberty Hyde Bailey in *First Lessons with Plants,* 1898

"Of all educational problems the foremost is this: to establish the harmonic balance between mind training for general culture and training the mind for success in the practice of a particular business or profession."

—William F. Ganong in *The Teaching Botanist,* (1899) 1910

"First, the aim to teach zoology so that it will afford good scientific discipline should be the very foundation of zoological teaching. Second, it should be aimed to present the information—practical, intellectual, aesthetic or moral in its bearing—which seems most valuable for liberal secondary education."

—Maurice A. Bigelow in *The Teaching of Biology,* 1904

". . . from . . . broad studies it may be possible to block out certain general needs of young people in present day society, to the end that science materials and learning experiences may be redirected to bring about a more effective adjustment to the problem growing out of these needs. . . . Science can contribute a fund of interpretative generalizations . . . a fund of appreciations . . . , a group of attitudes, or mind sets . . . [and] a method of attack on problems to aid the adjustment of individuals."

—Heis, Obourn, and Hoffman in *Modern Methods and Materials for Teaching Science,* 1940

THESE QUOTATIONS are a partial record of fifty years of evolution in aims. Corresponding changes in content and methods of teaching have accompanied the growth of the biological sciences, the development of a science of education, and the extension of a complete high school education to more than fifty per cent of our boys and girls.

Where We Began—1900

When the twentieth century opened, Darwin's theory of evolution had been generally accepted in scientific circles and had caused a reorientation of the teaching of botany and zoology, especially in the colleges. However, it had not penetrated into the thinking of the "masses." Those branches of biology, such as morphology, descriptive embryology and plant and animal geography, which had provided such strong indications of evolution were, of course, mature sciences. Bacteriology had taken the scientific and medical worlds by storm during the preceding 25 years. Its applications were just reaching the everyday life of America.

At the beginning of the century large numbers of villages and towns were without sanitary sewers. Fairly large cities often lacked adequate sanitary facilities. Shallow wells were common. Flies multiplied by untold millions in exposed garbage, stable manure, and outdoor toilet vaults, and swarmed over the food in unscreened shops, restaurants, and homes. Much of the milk supply was not pasteurized and, in innumerable instances, not even reasonably clean.

Half the beds in public hospitals were still occupied by typhoid patients and the death rate from tuberculosis was about 200 per 100,000. Responsibility for the transmission of malaria had just been placed on certain types of mosquito and, in a few months, Walter Reed was to show that yellow fever was carried by another species. Within a year the rediscovery and verification of Mendel's work were to be announced. Vitamins and hormones were unknown as such. Railroads and telegraph lines covered the nation. Telephones were spreading rapidly, while motion pictures and electronics were in the

embryonic stage. A few automobiles were on the roads, but there were no airplanes to carry people, germs, and insects from continent to continent. There was a philosophy of education and of science education but an experimental science of education and of science teaching did not exist. Objective tests of achievement and general intelligence were yet to be developed. However, science, invention, and education all had laid the foundations and built a part of the superstructure which was to develop so marvelously during the next fifty years.

A survey of the schools of America in 1900 would have shown wide differences in the use made of biology for education. In the one-room rural schools attended by most children, teachers fresh out of high school had no time for nature study except in an occasional story or an "object lesson" about a beautiful flower or an industrious animal during opening exercises.

Much more of what we may call biological content was included in the physiology and hygiene of the upper elementary grades. Legislation in most states required such courses along with a specified amount of teaching about alcohol and narcotics, much of which could, by no stretch of the imagination, be classified as science. The physiology and hygiene textbooks included some useful information about the body and about sanitation but they also presented much specific information useful only to an anatomist or physician.

However, when we think about the biological education of these rural children, we must remember that they had many direct contacts with living things. They helped plant and cultivate the truck gardens and field crops; they fed the livestock and poultry; they "bugged" the potatoes and helped their mothers put "louse-killer" on the chickens; they trapped rabbits and 'possums in the winter, gathered wild flowers and birds' eggs in the summer.

In contrast with the rural schools, the city elementary grades usually had teachers with normal-school training. And, of course, each teacher had only one or two grades to teach. In some rooms and some schools, nature study was a usual subject.

However, in general, there was little continuity from grade to grade and little uniformity between schools. Where nature study was taught the purpose was not primarily the development of accurate and useful ideas about the living world but of appreciation and morality together with some content for lessons in composition and art.

In some of the educational centers, leaders like Francis W. Parker and Wilbur S. Jackman had developed strong science curriculums which were intended to serve as the core of the elementary program of studies. During the preceding two decades other leaders had developed plans in which science instruction was to be incidental to and correlated with the study of history and literature. However, organized instruction in elementary science made little headway in the schools because of a lack of teachers trained in scientific subject matter and in scientific attitudes toward nature. Nature study was also held back by lack of trained teachers, but it was to gain headway more quickly, probably because of the appeal of its less "scientific" and more sentimental character.

At the beginning of the century, high schools were, for the most part, located in larger towns and cities. Only about one child in four entered, and, of those who entered, only about one-fourth graduated. Country children who had enough ambition or encouragement from home walked or drove a horse several miles to high school.

In the high schools, botany and physiology were standard courses while zoology was quite common. In 1900 about one-fourth of the students in high schools were enrolled in physiology courses. This would seem to indicate that practically every graduate of high school took physiology. No accurate data are available for botany and zoology before 1910. By that time the enrolment in physiology had dropped to 16 per cent of the high school population while 16 per cent were taking botany and about 8 per cent were in zoology classes. On the average, then, if we assume that all students graduated, each high-school graduate must have had something more than one and one-half years of biological instruction, or each student had

at least one year, and more than half of them had two full years. This is probably a better record of time spent in biology classes than the high schools of today can show.

However, the courses of that day would seem quite limited and "technical" today. Botany was almost entirely the morphology of flowering plants with many details about leaf shapes, inflorescences, and flower structure. In the spring much time was spent analyzing and identifying flowers. Zoology included the corresponding types of information about animals but there was even less of an opportunity to get acquainted with the animals that lived in the neighborhood. The physiology course was quite largely an amplified repetition of the eighth grade course with more technical details and terms. Yet there is evidence that physiology was beginning to creep into both botany and zoology. In 1904 Bigelow argued strongly that the repetitious human physiology should be combined with zoology and made more interesting by its applications in the animal kingdom in general.[6]

There is abundant evidence that the good teachers of 1900 made botany and zoology extremely interesting and valuable to their students, as good teachers of any subject can do. Many students retained that interest even though they went into unrelated lines of work. What did these teachers see in the biological sciences that they considered of value to their students? Over and over, in the professional talks and papers of the day, we find the leading biological educators supporting botany and zoology for their disciplinary and cultural values; these subjects trained the powers of observing, of critical comparison, of remembering, of thinking; biological knowledge was just as cultural as the humanities! The usefulness of biological information was mentioned but it was on the basis of its "disciplinary," "intellectual," "moral," and "aesthetic" values that it was considered useful.[6] And much of the supposed cultural and disciplinary value depended on the systematic organization of the subject fields.

In spite of the values claimed for the biological subjects and attained in the case of some students under some teachers, the work under the rank and file of science teachers was formal and

deadening. In general the biology teachers were criticized for having their students repeat the routines of dissecting and drawing "pickled" type specimens and of memorizing meaningless information to which the teachers themselves had been subjected in college courses. Much of the content was "so technical and detailed as to be of doubtful value to a liberally educated man. . . . There was . . . no time to learn anything about the life of animals or even of the existence of many important animals."[7] The students were immersed ". . . in excessive textbook and deductive work, which [tended] always to make them distrustful of their own powers, and [led] them to regard as the only real sources of knowledge the thoughts of others presented in printed books."[23]

Briefly, then, at the beginning of the century, biology in the elementary school consisted of varying amounts of disconnected nature study in the lower grades with rather standardized and informational physiology and sanitation courses in the upper grades of practically all schools. In an occasional experimental school, enthusiastic proponents of science had introduced systematic courses in general science for the grades. In the high schools most students studied one or two years of biology consisting of one-year courses selected from botany, zoology, and physiology. The textbooks were written by college specialists in the respective fields. The content and organization of the high school offering were to be revolutionized because of criticism, changing psychological theories, and a changing philosophy of education, promoted by an influx of children who would never go to college. The elementary schools were to see forty years of debate over the relative merits of "nature study" and "elementary science."

New Knowledge and Applications of Biology

One of the major influences on biology teaching since 1900 has been the rapid spread of applied biology into everyday life. "Pure" science has grown rapidly too, but it influences lower-level courses slowly unless it has some rather direct significance for the average citizen.

There has been outstanding progress in the control of in-

fectious diseases. Development and application of the principles of infection and immunity discovered during the last third of the nineteenth century have practically eliminated smallpox, diphtheria, bubonic plague, typhoid fever, and yellow fever from the United States and greatly reduced the infant-killing intestinal diseases. Tuberculosis has dropped from first place to seventh place as a cause of death, with a rate one-eighth what it was in 1900. The filterable viruses have been discovered, isolated, and crystallized. Chick embryos have been utilized for growing infectious agents and producing antibodies. The last two decades have seen pneumonia, venereal diseases, and many less specific infections yield to sulfa drugs and to penicillin and other antibiotics while new insecticides led by DDT have enabled man to control the insect partners of communicable diseases to an extent never before possible. As a result of these and other factors in the conservation of human life, the average expectation of life in the United States rose from about 50 years in 1900 to nearly 67 years in 1947. Thus the percentage of older people in the population has risen sharply and the degenerative diseases, such as cancer, heart disease, cerebral hemorrhage, and nephritis have become the leading causes of death.

Active study of the nutritional and caloric values of foods marked the openings of the century. Isolated knowledge of diseases cured by such things as lemon juice, pine-needle tea, and unpolished rice existed much earlier, but the story of vitamins seems really to have begun with the studies of Eijkman on beriberi about 1897 and Hopkins on rat nutrition about 1906. Before long, Vitamins A, B, C, D, E, and G had become common terms in nutrition. The third and fourth decades of the century saw the number rise to fifteen or more. During the same period, a number of the vitamins were being identified chemically so that they could be synthesized or otherwise obtained in large quantities for use in medical practice and in correcting the over-refinement of foods. Soon thereafter they began to be exploited as cure-alls by commercial interests. While the vitamin story was being worked out, it was found that traces of a number of chemical elements are essential in

nutrition. Iodine was one of the earliest of these and, as a result of the discovery of its importance in the body, "iodized salt" has greatly reduced the incidence of goitre in iodine-poor areas.

During the last decade, nuclear physics has provided radioactive isotopes which biologists are using as tracers in the study of physiological processes and in the treatment of such diseases as goitre and leukemia. The use of these tracers will lead to much more accurate knowledge of such basic processes as the synthesis and use of food substances in organisms.

Knowledge of the body's control of its own functioning by hormones has closely paralleled the knowledge of vitamins. At the opening of the century it was known that thyroid substance would help in the treatment of some goitres and that the islets of Langerhans in the pancreas were always diseased in cases of diabetes. The chemical product of the thyroid gland, thyroxin, was isolated by 1914 and synthesized by 1927. Insulin was extracted from the pancreas and used to relieve diabetes in the early 1920's. Through the half-century, knowledge of these and many other hormones—from parathyroid glands, adrenals, pituitary body, gonads, and other organs—progressed rapidly until a number of them were extracted, isolated, synthesized, and put to general use in medicine. The period is closing with startling news of the effects of pituitary and adrenal hormones in treating rheumatoid arthritis and nephritis which, in all probability, presages a new understanding of normal physiology and increased control of these degenerative diseases.

The discovery and study of plant hormones, during the period, led to their use for the control of flowering and the setting of fruit, the development of roots on cuttings, and the prevention of premature fall of fruit. One of these hormones, commonly known as 2,4D, has come into wide use for killing dicotyledonous weeds through the effects of overdosage.

At the very beginning of the century, Landsteiner discovered the existence in the human population of the four main blood types, A, B, AB, and O, and thus opened the way for successful transfusions, for the development in recent years of blood

banks, and for the discovery of sub-types. Further study of blood led to the production of huge quantities of dried plasma to combat shock in wounded soldiers during World War II, to the separation of plasma proteins into fractions useful for various purposes, the production of thrombin to control bleeding, fibrin to serve as absorbable packing and membranes in surgery, and heparin and dicoumarin to prevent unwanted clots after operations. Such discoveries and inventions, together with improved anaesthetics and new operating techniques, permit surgical miracles undreamed of in 1900.

There have also been revolutionary changes in the study of the mental aspect of human life. The use of intelligence and aptitude tests became widespread in the schools, the armed services, business, and industry. Behaviorism grew out of animal psychology and became part of the argument over the relative importance of heredity and environment. Many personality disturbances were traced to emotional shocks and repressions in childhood. As a result much attention is being given to the teaching of "mental hygiene" with the hope that it will help young people develop into happier and healthier personalities.

The rediscovery of Mendel's laws at the opening of the century marked the birth of modern genetics. Soon chromosomes were spotted as the probable carriers of heredity and fruitflies became famous as laboratory animals. Genes became as real as atoms and almost as common a subject of conversation among educated people. The new knowledge of genetics stimulated the activity of plant and animal breeders who developed many greatly improved varieties of poultry, livestock, grain, fruits, vegetables, and flowers. Many of the improved plants possess disease resistance which was combined with the other desirable characteristics by hybridization. The development of hybrid seed corn increased yields by 20 percent. Better plants and animals, mechanization of farm operations, irrigation of large areas, and improved soil management raised the agricultural output of our land to new records.

During this half century there has developed a new consciousness of the threat of soil erosion and deforestation and

there have been wide-spread attempts to reduce such losses by limiting land use, modifying farm practice, and restoring denuded areas. Much knowledge of fish, wild life, and forests has been gathered by field botanists and zoologists and used by greatly expanded government agencies and private conservation groups to maintain our valuable biological resources.

The many lines of applied knowledge emphasized in this account flow out of the fund of "pure" knowledge built up by the different fields of biological science. On the whole, the applications have influenced school science more directly than the abstract knowledge. However, the great reservoir of knowledge built up during this half-century is sure to feed new streams of practical application and to raise the general level of human welfare and human knowledge during the remainder of the century.

Population Growth of Schools and Science Classes

The increase in registration in our American secondary schools since 1900 has been phenomenal. The number of secondary school subjects available to students has also increased greatly. The last comprehensive study of subject trends included figures through 1933-34.[33] A report of a less complete study includes figures for 1940.[26]

The total enrollment in public high schools in the U.S. in 1900 was 519,251. In 1910 the figure was 739,143; in 1915 it was 1,165,495; the number in 1922 was 2,155,460; in 1928, 2,896,630; and in 1934 the total number in public high schools was 4,496,514 students.[33] By 1942 it had risen to nearly 7,000,000.

The percentage increase in high school enrollment from 1900 to 1910 was 42%; from 1910 to 1915, 57%; 1915-1922, 85%; 1922-1928, 34%; and 1928-1934, 55%. Thus, it is seen that there were large increases in high school enrollment for each of the periods listed and for the total period 1900 to 1934 the increase in high school enrollment was 866%. In other words the high school enrollment in 1934 was 8.66 times as great as in 1900. From 1900 to 1930 the proportion of youth of 15 to 17 years enrolled in the same schools increased from 40% to 67% of the total population

in the same age groups. The offerings rapidly increased until in 1934 the list of studies rather commonly offered included 111 subjects. Thus the number of subjects which might be considered as competing with biology for election by students rapidly increased from period to period.

In 1900, 27.42% of students enrolled in the high schools were in physiology classes. Botany and zoology were first listed in the survey in 1910 with enrollments of 16.8% and 8.0%, respectively. With the drift away from emphasis in formal values of subject matter and increased emphasis on functional values as a result of the changing character of the secondary school population, general biology was added to the curriculums of more and more schools. This new subject included much of the subject matter of the older zoology and botany, but it emphasized material that would help meet the responsibilities of daily living. The growth of enrollments in general biology has been quite rapid, increasing from 6.9% of the total secondary school enrollment in 1915 to 8.8% in 1922, 13.6% in 1928, and to 14.6% in 1934. The actual numbers in biology classes rose from 80,403 in 1915 to 656,520 in 1934.

While biology gained rapidly in popularity, botany and zoology gradually declined until by 1934 they had almost vanished from the secondary school curriculum with enrollments of 0.9% and 0.6%, respectively. The registrations in all the biological science offerings in the secondary schools combined indicate that few secondary school students did not study one or more of the biological sciences at some time.

While complete figures are not available to show the trend in biological enrollments since 1934, the survey by Hunter and Spore in 1940 gathered data concerning 323 secondary schools representing every state in the Union.[26] The figures for biology from 323 schools with a total school enrollment of 467,738 and with an enrollment in biology of 87,821 showed that 18.7% of the total number of students were in biology classes. This represented 29.3% of the 302,809 students then enrolled in science classes. Thirty-three percent of science students were in general science, 12.4% in chemistry, and 7.95% in physics. (The figure for

general science is hardly comparable with the others, since it represents enrollments in that subject in the different years of the junior high school as well as enrollments in the four-year high school courses.) Biology has not only made substantial gains in enrollment since 1915, but it has more than held its own among the science subjects of the secondary school.

From 1900 to 1910, the number of secondary school pupils in physiology classes decreased from 27.42% to 15.32% of the total secondary school population. In 1915 the number was 9.48%; in 1922, 5.08% and in 1934 only in 1.82%. It is reasonable to believe that in many schools physiology was displaced by biology. Figures showing enrollment in classes in sanitation and hygiene first appeared in the Bureau of Education reports for 1922. The enrollment reported was 6.06%; in 1928 the figure was 7.84%, and in 1934 it was 6.51%. The enrollments in these classes probably account for a part of the reduction in physiology enrollments. The reasons for this shift seems to have been related to the added emphasis that was being placed on functional values and to the state requirements that make mandatory the teaching of the effects of alcohol and narcotics on health.

Subjects in vocational applications of biology have been offered in many secondary schools. Agriculture is a basic high school science in many of the Great Plains and mid-western states. In 1910, 3.78% of secondary school pupils were enrolled in classes in agriculture; in 1915 the number was 7.17%; in 1922 the number had fallen to 5.11%; and in 1928, still farther to 3.66%; in 1934 the enrollment was 3.55%.

The rapid growth in high school biology enrollments occurred during the reaction against formal discipline and against preparation for college as the chief end of science teaching. The introduction and development of the course seems to have resulted from an attempt to meet the demands for training youth to live effectively in the changing society. It is highly significant that the entire secondary school was rapidly changing from an institution that trained a select portion of young people for leadership to one that had to meet the needs of all young people for living in a civilization growing rapidly in complexity.

Evolution of Aims and Objectives

In dealing with the aims and objectives of teaching, we must always be careful not to confuse those stated in professional reports and methods books with the ones which really guide teachers in the classrooms. The purposes professed by science educators and voluble teachers may have little connection with practice. Changes in objectives that are to influence teaching probably require anywhere from ten to twenty or more years to filter down from experimental schools to textbook writers and into the schools, or from methods courses to a new generation of teachers and thence to the classrooms. Nevertheless we can identify some general tendencies in the philosophy of biological education during the past fifty years and connect these tendencies with changes in courses, course content, and methods of teaching.

We have already seen how, at the beginning of the century, biological teaching in the high school was dominated by belief in the value of organized science for training the various faculties of the mind, such as the power of observation, memorization, etc. Culture was also often mentioned as a desirable attainment to which botany and zoology could make a great contribution. Hygiene and physiology were hardly considered science because they had been forced into the curriculum to provide purely utilitarian information and to teach habits that would improve the health of the pupil and his neighbors.

It should be recognized, however, that the professed aims were evidence of some very real influences acting on the content and methods of teaching. The high schools were mainly preparatory schools for students bound for the professions by way of college. Standards were set by the entrance requirements of the colleges. The textbooks were written by the professors who had set up the college entrance requirements, and they were taught by men and women who had learned their botany, zoology, and physiology in the classes of those same professors or others like them. Small wonder, then, that, in practice, high school biological courses amounted to watered-down versions of college courses.

Before the end of the first decade of the century, the philosophy of formal discipline and faculty psychology, in the original sense, had begun to lose ground. The best thinkers in the field were pointing out how useless and ineffectual much of the teaching was, how far from the life of the average person were the details of plant and animal morphology commonly emphasized, how both the botany teacher and the zoology teacher should point out the general principles illustrated by the organisms studied, how repetition could be eliminated and the significant principles could be better emphasized by teaching animal physiology in connection with zoology.

By the end of the second decade of the twentieth century the leaders in educational philosophy had decided that the real ends of teaching were not so much proficiency in the special subjects as they were the development of effective and happy citizens. Out of this emphasis came, in 1918, the statement of the "seven cardinal principles," or aims, of education—healthful living, worthy home membership, worthy use of leisure time, command of fundamental processes, vocational effectiveness, earnest citizenship, and ethical character.[13] In 1920, science teaching was interpreted in the light of these aims by a report under the title, "The Reorganization of Science in Secondary Schools."[14] This report urged that the sciences should be organized and taught so as to contribute to the "cardinal" aims rather than to reproduce in the minds of the students the organized knowledge of the special sciences.

By the end of the third decade the movement toward a "functional" use of science in education had really begun. During his survey of science instruction reported in 1932, Beauchamp found science teaching to be a mixture of traditional practices and innovations. There was still a great deal of faith in mental discipline but science was being reorganized to provide information and abilities useful in everyday life as well as knowledge of the place of science in society.[4]

Leaders in science education had been examining the functions that science could perform in the development of boys and girls. They identified the contributions of biology, as (1) the un-

derstanding and ability to use in everyday life the major principles and concepts of science as they apply to the living world; (2) the ability and desire to use the scientific method in solving the problems of life; and (3) certain emotionalized habits such as appreciation of nature and of science, interest in the biological environment, and "scientific attitudes." E. R. Downing and other workers did a great deal of research to identify the generalizations that are most useful. They analyzed the content of textbooks, newspapers, magazines, children's questions, and other materials. They studied the "scientific attitude" to find out what factors are involved and publicized their conclusions.

During the same period, Henry C. Morrison and others were developing the unit plan of teaching as a more effective way of attaining the specific objectives identified by research workers in science education—principles and concepts and the application of these to an understanding of significant aspects of the environment.[31]

Textbooks embodying the analysis of the environment and of the sciences in terms of "big ideas" and organized for teaching by the unit plan began to appear and, in 1932, the National Society for the Study of Education produced its noted report, *A Program for Teaching Science.*[35] This report marked the zenith of the emphasis by leaders in science education on the so-called big ideas, but, in general, its philosophy is still widely accepted with certain qualifications and modifications. However, it should again be remembered that practice lags far behind theory. In this same Thirty-first Yearbook, Downing pointed out that only between one-fourth and one-half of the content of high school biology textbooks contributed to the understanding and application of biological principles.[35]

Most textbooks published after the appearance of the Thirty-first Yearbook subscribed to its philosophy and their contents were influenced by its statements of objectives. Some even stated the principles and concepts as the headings and subheadings of their "units." General biology and general science were more susceptible to these changes than were physics and chemistry. As will be pointed out later, the teaching of science

in the elementary school was also generally influenced by this report.

In the years that followed the publication of the Thirty-first Yearbook much research was directed to selecting the principles most important in general education. In 1945, Martin published the results of the most extensive study of biological principles.[30] His list of the one hundred principles most important for general education, according to the findings of his study, was considered of such significance that the United States Office of Education distributed it as a mimeographed bulletin. Then, in 1947, in its Forty-sixth Yearbook, *Science Education in American Schools*, the National Society for the Study of Education endorsed the objectives stated in its Thirty-first Yearbook but gave equal emphasis to other more general objectives.[41] When compared with the earlier yearbook this report seems definitely to represent a lessening of the emphasis on the objectives characteristic of the sciences as special subjects and a greater stress on scientific attitudes, "scientific" thinking, and using science to help boys and girls live effectively. Neither yearbook attempts to set the objectives of the high school or junior high school apart from those of the elementary grades although, for convenience of teachers, there are special discussions for each level.

Partly because it considered the entire twelve grades as a sequence, the Thirty-first Yearbook marked a significant trend in the philosophy of elementary school science. The attempt to graft a complete science sequence on the elementary curriculum during the period 1890-1905 had almost completely failed. The nature study idea "took" and grew much better. It probably reached its highest level of popularity during the early 1920's. "Nature Study," as indicated by the quotation on page 80, aimed primarily at producing desirable effects on the child rather than at the development of a knowledge of the sciences dealing with plants and animals. Probably because sentimentalizing and moralizing on the basis of living things appealed alike to teachers and pupils and because the movement was well implemented with teaching aids prepared by enthusiastic leaders, the move-

ment gained a great following that lasted into the 1920's and beyond. The zenith of claims for nature study was reached in the Fourth Yearbook of the Department of Superintendence, National Education Association (1926). This publication listed some seventy "aims and objectives" of nature study and elementary science. It furnished a list of activities for each grade in which key numbers indicated the particular aims to which each activity contributed. For example, "Feeding the Squirrels," in the kindergarten was supposed to develop such qualities as "ability to perceive the truth," "belief in the value of truth," "realization of the wisdom of nature's laws," and some fifteen other aims. Such far-fetched claims may not have been characteristic of those who best understood the values of nature study, yet the fact that they could be published by an organization of such standing as the Department of Superintendence indicates the status of the movement.

Growing dissatisfaction with nature study together with the development of more scientific techniques for curriculum construction began to influence the elementary science program during the middle 20's. Then, in 1927, Craig published the results of extensive research to determine a science curriculum for the elementary school.[15] The products of this study, later embodied in a series of eight textbooks for the elementary school[16] marked the rise of a true general science curriculum for the schools. In the Thirty-First Yearbook, Craig and Miss Florence G. Billig related the aims of science in the elementary school (Grades I-VI) to those in the junior high school grades and the senior high school. The suggested curriculum provided for a continuous development of both physical and biological concepts related through the first twelve grades. Other series of textbooks for the elementary school quickly followed that of Craig and his co-workers. Some of these were truly elementary science but nature study content persisted in others under the name of elementary science. Courses of study were characterized by the same influences; some followed the elementary science trend and some merely kept the nature study material

and called it science.[45] These rival tendencies still persist, especially in the first six elementary grades.

In the seventh and eighth grades, the general science of the ninth grade became a dominating influence. Textbooks for the junior high school extended the aims and material of the general science course downward but included more biological material than was characteristic of the ninth grade course. Thus there came into existence for the first ten grades a well integrated program which has been put into effect in many school systems. This program is based on the belief that scientific knowledge and experience with the natural world, in both its physical and biological aspects, contributes to the complete development of children but that these influences are more effective when they are organized in terms of the aspects of the environment and of the children's own problems rather than in terms of the specialized sciences.

During the past twenty years the traditional objectives of the special subject fields have been strongly opposed by what may be labelled the "progressive influence." The science yearbooks of the National Society for the Study of Education achieved something of a middle-of-the-road position, but there was constantly at work a movement characterized by an emphasis on the child and his "needs," on school being a part of life and not preparation for life, on the use of science content and scientific method for solving the problems that come up in living, rather than on the mastery of any specified body of knowledge (whether organized as a special science or not), on democratic rather than autocratic procedures in the classroom. This movement tended away from the teaching of any special science course (even general science or general biology) and toward integrating science with other fields in "core curriculums." Often it resulted in the incorporation of material from other areas into "biology" courses. For example, much psychology and social studies material was, in some cases, included with biology in studies of the "life span," or of "marriage and family life," or of "mental health."[28]

The movement characterized here was not in reality new but

was related, in spirit if not by direct descent, to the causes which produced "nature study" and the reports on reorganizing the secondary school in 1918 and 1920. In the 1930's the movement was led by the Progressive Education Association which was responsible for the production in 1938 of *Science in General Education.*[36] This report emphasized the type of general ends of education which became prominent as the "seven cardinal principles" and were restated by the Educational Policies Commission as four groups of objectives, those of self-realization, human relationship, economic efficiency, and civic responsibility.[37] *Science in General Education* restated the objectives in terms of four "basic aspects of living": personal living, immediate personal-social relationships, socio-civic relationships, and economic relationships. It identified the personal characteristics essential to democratic living which science teaching should help develop as social sensitivity, tolerance, cooperativeness, creativeness, self-direction, esthetic appreciation, and the disposition and ability to use reflective thinking in the solution of appropriate problems.

In each of the basic aspects of living, certain "needs" of adolescents were found. Biological science material was shown to contribute to the following needs related to personal living: "personal health," "self-assurance," "a satisfying world picture and a workable philosophy of life," "a range of personal interests," and "esthetic satisfaction." In personal relationships the needs were stated as "increasingly mature relationships in home and family life and with adults outside the family," and "successful and increasingly mature relationships with age mates of both sexes." Biology was shown to have contributed to both these needs.

In the area of social-civic relationships, biology contributes information about and experience with public health to meet the need of "responsible participation in socially significant activities." Under economic relationships, biology has a definite contribution to make to the needs of certain students in "guidance in choosing an occupation and preparation for a vocation." The report showed how generalizations of the Thirty-first Yearbook

could be used to meet the named needs of adolescents and gave suggestions of activities suitable for helping bring the necessary science to bear on the problems of students. Throughout the report, the responsibility of science teachers for the complete development of their students was emphasized.

The type of thinking that dominated *Science in General Education* was also a strong influence in publications of the National Committee on Science Teaching of the American Council of Science Teachers which appeared in 1942. The titles of two of the four reports indicate the emphasis: *Science Teaching for Better Living;*[1] *Redirecting Science Teaching in the Light of Personal-Social Needs.*[2] In the latter report there is a tendency toward the "atomization" of objectives to such an extent that organization of a practical curriculum to attain them becomes very difficult if not impossible. Long checklists of objectives collected from teachers and supposedly validated by judgments of teachers are provided in eight different categories at each of six grade levels. At the junior high school level, there are such objectives as the following: for health—the habit of sleeping at least nine hours daily; for safety—readiness to render simple first aid and to summon technical assistance when needed; for conservation—"growth in the development of abilities and conservation tendencies in fire prevention, tree planting and care, wild flower protection, prevention of erosion, intelligent observance of fish and game laws, etc." The list for this level states about seventy different objectives for the science teacher, about twenty-five of which are definitely related to biology (including health) and fifteen of which are so general that a biology teacher has no more responsibility for them than any other teacher or a parent.

The Forty-sixth Yearbook of the National Society for the Study of Education, *Science Education in American Schools*, exhibits the influence of the "progressive movement" in a number of ways.[41] As mentioned earlier, it endorses "big ideas," or general concepts, and the understanding of science principles as objectives. Yet it does not suggest the teaching of units based on such concepts to the point of mastery by all pupils. Instead it

insists that such objectives are "directions" of growth along which different pupils must be expected to develop at different rates, each in his own pattern. There is considerable emphasis also on learning by doing, so that knowledge really functions, and on pupil-teacher planning in science classes.

Questionnaire studies made in 1930 and 1941 have revealed significant changes in the objectives accepted by teachers themselves.[26] The attitudes and techniques of the scientist as used in reflective thinking were rated by the teachers as much more important in 1941 than in 1930. In 1930 preparation for college was rated first by senior high school teachers and tenth by junior high school teachers. In 1941 this objective fell to 23rd and 29th, at the same two levels. At the top of the list in 1941 stood knowledge, understanding, and appreciation of the environment, and understanding of personal health needs.

A study of the aims and objectives as they have been expressed during the past fifty years shows clearly a series of significant changes growing out of conflicting influences. Many private and public schools are still greatly concerned with preparation of students in the special sciences for college entrance or for vocational purposes and thus tend to preserve the traditional aims of organized subject matter especially in botany, zoology, and physiology courses in the eleventh and twelfth grades. However, in most schools the biological content used in the first ten grades has largely lost its special science objectives and is, by profession at least, used to develop understanding and control of the environment as it relates to the lives of boys and girls in their own homes and communities and to help boys and girls solve their problems and meet their needs in suitable ways.

Application of the less traditional aims of teaching is producing radical instructional material in a few schools that have the necessary courage and leadership. The next fifty years may well produce a balance between the value of an organized knowledge of certain areas of biology and the value of applied biological knowledge in the practical aspects of living. Some of the objectives of teaching biological materials are universal but some of the more specific ones change with the community. Science

teaching in the future will in all probability continue the trend toward a flexibility which will permit functional adjustment to local needs and to teaching materials available in each particular region.

Changes in Courses and Their Content

As we saw earlier, the secondary school biological courses at the beginning of the century were usually a year of botany and a year of zoology. Occasionally a half year of botany and a half year of zoology combined were considered a year of biology. The year courses were planned to meet college entrance requirements and to prepare students to enter college classes in these subjects.

The botany which was largely morphology of plant structures was believed to have high value for mental discipline. Much emphasis was placed on laboratory work for its disciplinary values. The groups of lower plants including algae, fungi, mosses, and ferns were studied in detail. Laboratory notes and carefully labeled drawings were required. The growing fear that some of the flowering plants would soon be extinct led most teachers to relax the usual requirement of a herbarium of fifty pressed specimens of flowering plants. In the first decade of the century, systematic morphology began to lose favor and there was a shift toward plant ecology, plant physiology, and economic relations of plants. Botany became less formal and new materials with functional values were added.

The early emphasis in zoology was on anatomy, comparative anatomy, and classification. The students were required to make dissections of prepared specimens. Careful laboratory work consisted mainly in finding and drawing what the laboratory manual indicated should be seen. The trend, beginning with 1900, was to return to an emphasis on natural history and on human welfare relations.

A committee of the Biology Section of the Central Association of Science and Mathematics Teachers which reported in 1904 made recommendations which were significant as indicating the trend of thought at that time with regard to course content in

biology. The report stated, "Morphology, as an end, has no place in the secondary school botany and zoology . . . how the animal lives is the keynote. . . . The relation of plants and animals to man (economic phase) is growing more and more in favor. . . . Physiology is always an important part (of plant and animal study). The principle of evolution should be taught at the discretion of the teacher. It should form a part of every course, but not in a formal way."[9]

Previous to 1900 it was the rule in both botany and zoology to use what was known as the logical arrangement of subject matter. This was the evolutionary plan, proceeding from the simple to the complex. This was held to be inherent in the life sciences. As a matter of fact, it was handed down to the secondary schools from the college. The textbooks were usually written by college professors. The secondary school teacher frequently made use of notes he had taken or prepared in elementary college courses. The "lowest" forms were studied in detail and usually there was not sufficient time left to get an acquaintance with the "highest." This use of materials put undue emphasis on facts with the aim of complete presentation rather than selection of subject matter highly significant to the pupil. The "logical" type of organization did not take into consideration the availability of living materials to be used in the laboratory or studied in the field.

After 1900, there was a gradual departure from the "logical" order to the seasonal arrangement of materials. Thus, according to this change, the courses were arranged, in general, in such a way that studies of particular materials could be made in the laboratory at times when they could be collected or observed in the field where they were alive and in their natural habitats.

According to the seasonal arrangement, the course in zoology was organized in such a way as to study insect materials in the fall semester and the birds during the time of migration and nesting in the spring. Thus class and individual student field work could be planned around insect studies and relations in the fall and bird studies in the spring.

In botany, the general tendency was to start the course in autumn with a study of fall flowers, seeds, fruits, weeds and

dispersal, together with ecological relations and their relations to man's welfare. After that, the course included a study of the plant groups, from lowest to highest, in their systematic relations. The study of seed plants was pursued in the spring when conditions were most suitable for study of structure in relation to function of the parts of the higher plants, and ecological relationships, both in the laboratory and in field studies.

During the first decade of the century, the practice of combining botany, zoology, and physiology into an introductory course in biology became quite prevalent. The course has been of two types: one in which the materials of the three sciences are treated separately, the other in which there is an integration of the materials of the three subjects developed in such a manner as to apply to the solution of problems as they occur under topics or units of instruction. The integration develops naturally in the organization of subject matter around the so-called units or "big ideas."[31] In this type of organization of subject matter, the emphasis is on the development of understandings, desirable attitudes, appreciations, etc., rather than on the accumulation of isolated facts.

The seasonal arrangement of subject matter has been favored by many teachers of biology. A notable example of a course in biology arranged on the seasonal basis consists of an organization around two general headings, or units, "I. The Need of Food is Common to All Living Things" (Nutrition), and "II. All Living Things Must Reproduce if They Survive, How the Species is Maintained, Heredity."[5] Many writers of textbooks using the unit organization state that the order of units may be hanged in various ways in order to facilitate use of seasonable living materials.

Following the shift in emphasis shortly after 1900 from that on college entrance and formal discipline values to functional values, there was the need for more and more living materials for use in the biology classes throughout the year.

In many cases plans for new high school buildings provided for a room fitted with tanks, cages, benches, etc., to provide for the study of life histories, external structure, protective features,

food habits, etc., using living forms as needed during the year. A suitable window arrangement or a small greenhouse provided fresh plant materials for structure studies or experimental purpurposes.

The tanks and aquaria were prepared in such a way as to simulate the environment in which the different animals live outside. Clams, crayfish, fish, toads, frogs, salamanders, turtles, harmless snakes were available at all times for observation or study. Eggs of fish hatched into fry, and salamander and frog eggs hatched into tadpoles. The young of white mice, guinea pigs, and rabbits were born in the laboratory or live-room where they later grew to maturity. A hen produced a brood of chicks and incidentally material for showing chick embryos in various stages of development. An observation hive with bees and a regulation stand of bees could be observed outside on the window sill. Pupils could watch mosquitos and blue-bottle flies pass through their different stages; large Polyphemus caterpillars spun cocoons in the laboratory in September, and the pupils saw the moths emerge in February.

These are some of the materials used in the new types of biology course which have emerged during the past half century. And then there are materials which the particular community offers, such as vacant lots, home grounds, parks, wild life sanctuaries, observatories, local laboratories, museums, farms, street parkways, and forest preserve areas.

One of the results of the crowding of the secondary schools in the years following 1915, was a great reduction in the facilities for laboratory and demonstration work in biology requiring live materials. Crowded classes, the double shift, etc., demanded more and more of the teacher's time and more and more space at the expense of some valuable features of biological instruction.

A study by Caldwell and Weller was made in 1932 to determine the opinions of college biologists concerning the factual and topical content of high school biology[12] An analysis of the content of 21 secondary school biology textbooks was prepared and submitted to 37 college biologists who were asked to give

their opinions as to the suitability of topics for high school biology and also add others that they thought desirable.

Nearly all of the judges would give slightly less attention to classification than is given in the textbooks. "Geographical distribution of plants and animals is recommended by four-fifths of the judges." "Almost all of the judges would include care of special human structures, public health, and study of foods." "In ecology, the aspects recommended by nearly all the biologists are economic value of plants and animals, insect pest control, and conservation of wild life." Processes of metabolism would be included by almost all of the judges. Heredity and environment would be included by almost all, but not emphasized. "Theories of evolution would receive scant attention." It is not claimed that such an inquiry can provide "final evidence regarding the content of the high school biology course," yet it is claimed that the professional standing of the 30 reporting biologists should add weight to the validity of the findings of the study.[12]

Martin's survey of research studies relating to newspapers and magazines reported in 1945 represents another belief as to how the content of courses should be determined. He states: ". . . the kinds of scientific materials appearing in magazines and newspapers should furnish evidence as to some of the basic understandings which must be developed in courses in science to permit of an intelligent reading of these materials." The studies of these materials reveal "definite agreements and trends which are of importance for the organization and presentation of the materials and learning experiences of biology for purposes of general education." His general conclusions were as follows:

1. Biology is the most common branch of science occurring in the representative newspapers and magazines selected.

2. The most important topics, on the basis of frequency of occurrence, are: human biology, health and disease; animal biology; foods and nutrition; and plant biology.

3. Later studies seem to substantiate the finding reported in the pioneer study by Finley and Caldwell, that ". . . the whole question of biology, so far as the public press is concerned, is

homocentric, as [the] articles, either directly or indirectly, relate themselves to biology as it affects man."[22]

4. Close agreement of findings of the different studies is held to indicate that "the biological topics discussed in newspapers and magazines constitute a valid guide to the biological phases of science which are of consistently great interest because of close relationship of every day experiences."

Martin states, "On the basis of all the data, therefore, the conclusion seems to be justified, that any reorganization of biology to serve the purpose of general education should be in the direction of a more functional treatment of the materials presented and a greatly increased supplementation of the textbooks by the use of those materials related to the topics shown to be of importance in the studies surveyed."[29]

An editorial note by Potzger voices an opposing view of content selection: "The editor is of the opinion that newspaper articles cannot determine the basis for a course in science; the subject itself determines that. However, newspaper interests can point to desirable additions which could be made to the basic things, if time permits. The fundamentals for a course in science still are: to acquaint students with the great basic laws of an orderly world, and to develop a desire to apply scientific procedure and thinking to the problems of life."[34]

In an address given at the 1946 Annual Meeting of the National Science Teachers Association, Paul F. Brandwein recommended methods of reorganizing biology in such a way as to meet the needs and interests of the pupils more adequately. He stated: "The acceptance of a teaching philosophy based on the needs and interest of students precludes rigid courses of study, inflexible teaching procedures, unsympathetic administration. But it does not mean that the experiences around which the course is organized are derived entirely from the student's interests. A need is defined as an interaction between the student and his community." "The student's interests serve as motivations, not as end."[11]

Brandwein says further that, "Reorganizing biology teaching to meet the needs and interests of youth involves first, a willing-

ness to meet youth half way in planning content." This seems to mean that the reorganization is under the supervision of a superior teacher who builds upon the experiences and background of the pupils with whom he is working. Since the course as organized usually "centers around the areas: nutrition, human physiology, behavior, disease, the life span, heredity, evolution and anthropology, and biotic production," it would seem that its organization also represents to a high degree the guidance of subject matter experts.

In brief, biology courses have shifted away from special-subject content patterned after college courses to content selected and arranged to develop in students the practical, esthetic and intellectual values of biological knowledge in everyday living. The century was only a few years old when botany and zoology courses began to change. During the second and third decades courses in general biology largely replaced botany, zoology and physiology courses. This change gave opportunity for much experimentation and many types of organization were tried in courses of study and textbooks. Different ones emphasized the biology of man, health, practical information, the great generalizations, social biology, conservation, and the spontaneous interests of students. Each variation called attention to some value of the area and had its influence on the biology courses of 1950. The different features of these courses would sometimes interest and sometimes disappoint and shock a biology teacher of 1900.

Such a pedagogical Rip Van Winkle would probably notice that much more time and attention is given to orienting students in their study of the subject, to helping them understand what biology is and the bearing it has on their lives and on the welfare of everyone. The current emphasis on scientific attitudes and scientific methods would also be an obvious innovation.

Our visitor from 1900 would look in vain for the familiar treatment of group after group of organisms with great detail and thoroughness. Instead he would find one or more units which attempt to acquaint students with the great diversity of living things by describing the principal groups of plants and

animals and illustrating them with a few familiar or important members. The kind of detail which once made up the bulk of biological courses now serves only to develop or illustrate some principle, or else is included to help students recognize common species of organisms, to catch the interest of students, or to be of direct use in some other way. One result of the decreased emphasis on facts as such has been a reduction in the number of technical terms used.

Some of the shocks suffered by our visitors might well be caused by the current emphasis on mammalian reproduction and embryology and by the inclusion of discussion of venereal diseases as important examples of infectious diseases. But then we could draw his attention to the expanded treatment of such topics as organic and degenerative diseases, the races of men and behavior patterns which have been encouraged by social problems of recent decades. And he would soon lose himself in the fascinating news about vitamins, hormones, and antibiotics.

Administratively biology has evolved into a one-year course offered or required in the ninth or tenth grade and taken by somewhere from 50 to 60 per cent or more of the high school population. Such units as those on nutrition, physiology and infectious disease are frequently duplicated in the general science of the seventh and eighth grades or of the ninth grade. In the smaller high schools no further study of biology is available except where there is an opportunity to take a vocational agriculture course. The large city high schools which have developed during the last 25 years frequently offer excellent elective courses in advanced biology, physiology, botany and zoology for the benefit of interested and capable students.

Changes in Methods of Teaching

To appreciate the changes in the ways of teaching biology that have taken place since 1900, one need only examine typical textbooks, laboratory manuals, and workbooks of then and now. In the students' books of the earlier period one seldom found questions at the beginnings of the chapters. The introductory paragraphs were brief and made few, if any, connections with

the life of the students. Answers to any questions at the ends of the chapters were to be found in the chapter itself, not by thought or from other sources. Seldom were there any references to other books or reading materials. If so, they were to other material much like the textbook itself, or perhaps more advanced. Directions for laboratory study were ordinarily at the back of the book or, more often, in a separate manual, thus indicating the tendency to carry on the two methods of study at separate times. There were no workbooks as we understand the term today. In the laboratory manuals for botany and zoology, one found minute directions about how to prepare laboratory notebooks, how to make and label drawings and write up notes and experiments. The instructions for each exercise were quite specific and detailed.

Contrast with those books of an earlier day the typical modern high school biology textbook. Each unit is introduced with a picture in natural colors closely connected with the problem of the unit. Somewhere on the first page or two are several intriguing questions to be discussed and answered during the study. Each unit opens with an interesting introduction which points out the relation of the unit to the student himself, to his community, and to the welfare of the country as a whole. It may include some interesting historical or biographical anecdote. Then the student comes to the first main division of the unit. He finds its title is a significant question related to himself or to something he knows about. Included with the reading material are probably the directions for a few laboratory exercises, but only such directions as are necessary to help him follow the main points of the investigation. There are few or no references to technical details that have no bearing on the problem he is studying. Instead of detailed instructions there may be only the suggestion that he can study certain material to find out more about the problem. He must work out the details himself.

At the end of the unit there is a great variety of exercises, projects, and suggestions for supplementary reading. Some of these bear directly on the subject of the unit, others point to biographical and other connected material, often to pamphlets

which may be secured for a few cents or for the asking. Here, too, in the teacher's manual are lists of motion pictures for use during the study of the unit. Among the exercises there are apt to be "self-tests" in objective form, some on the subject matter, and some designed to see whether the student can interpret data, draw valid conclusions, and, in general, think straight.

If the teacher wishes, his students may have a carefully prepared workbook which includes a great variety of exercises to do, observations to make, experiments to do, and self-tests to take. The directions even hint that, instead of doing all his preparation as home work, the student may be expected to go about his study during the regular class period as well. At the end of the unit the teacher may have available a ready-made objective test which is easily and quickly scored. At the end of the year he may give a standardized test to compare the general effectiveness of his teaching with that of other teachers the country over.

To understand how such changes in teaching biology have come about is difficult because they are the results of so many interacting influences. Changes in scientific knowledge, in teaching aids, in the population of our classes, in our aims, and in teachers themselves have all interacted so that any attempt to examine one aspect distorts our view of the whole. Neither can we understand the whole without turning our attention to the parts.

During the first two decades of the century we find little evidence of major changes in methods of teaching biology. The better teachers made judicious and effective use of individual laboratory work, demonstrations, class conferences, textbook recitations, and an occasional lecture illustrated with lantern slides. In general there were daily assignments to be followed up at the next class meeting. Laboratory notebooks must contain certain drawings, carefully labeled. Physiological or other experiments might be done individually or by committees, but each must be written up in a prescribed manner: purpose, apparatus, procedure, results, conclusion.

Here and there a teacher was using a "developmental" method —following up a topic with his class, stimulating them to search

reading material, do experiments or consult community authorities to find the answers to their problems. Such departures were encouraged by the appearance of general science and general biology in the place of the more specialized courses. Yet, for the most part, biology courses were made up of extracts from the specialized courses and taught in much the same way.

During the 1920's new plans of teaching developed. Morrison and science teachers who were thinking along the same line gained a considerable following for the "unit plan" of teaching. Assignments were not made day by day but, after a period of careful introduction the students went about their study of the unit for a week or a month, during the class meetings, if the teacher was a strict follower of Morrison, or both inside and outside the classroom, if he was not. The students were called to attention for group activity only when it was necessary or appropriate. Demonstrations and experiments were done at appropriate times. When most of the students had completed their study of the unit, the teacher conducted some organizing and expressional activities and administered a unit test.

The popularity of the unit plan of teaching, based, as it must be, on carefully organized teaching units, was increased by the appearance of textbooks which incorporated all the directions, exercises, and experiments needed for the study of each unit. They included also references and suggestions to encourage the students to do much supplementary work. Workbooks also appeared for use with the textbooks not organized on the unit plan, or for use without any single textbook. Usually they provided blank spaces for the students' written work, and, often, there were shortcuts for laboratory work such as partial drawings, drawings to be labeled, tables to be filled in, and so on. The "self-teaching" textbooks and workbooks were a great boon to busy teachers who wished to teach by the unit plan but who lacked the time or the inspiration to prepare their own study guides.

The unit plan of teaching coupled with the progressive education movement developed still further during the 1930's and 1940's but only where there were thoughtful and able teachers.

In some classes the introductory period became a time when the teacher and students together chose some problem they wished to study and planned how they would study it. Different students did different things and brought their contributions back to the class. Then further planning and study went on. Naturally under the guidance of the best teachers this plan of teaching has led to less specialized content and to the study of problems that are more significant to the students. In the hands of less capable teachers it has led to undesirable superficiality. (It should be pointed out here that when the teacher really lets the class help plan the work, there is usually a departure from Professor Morrison's concept of the unit.)

The unit plan and cooperative-study plan just discussed have led many biology teachers to a different view of the laboratory. Instead of visualizing the ideal high school biology laboratory as a room with rows of microscopes, jars of a variety of pickled specimens, and stacks of glassware adapted to a certain series of laboratory exercise, the classroom-laboratory is seen as a workroom with a great variety of tools, adaptable apparatus including some microscopes, supplies, and living plants and animals that students can use to solve the problems that arise during the study. The development of these newer methods of teaching has led to the use of a much greater variety of reading materials and to more adequate use of community resources for the study of biology.

Biology teachers in today's high schools are using every possible plan of teaching, through textbook-assignment-recitation to "pure" student-teacher planning. In 1942 Hilgers reported the result of questionnaire replies from 277 high school science teachers in Minnesota.[24] Biology and general science teachers indicated that they used class discussion, supervised study, textbook assignment and recitation, references and reports with about equal frequencies. Problem, lecture, project, and contract methods were noticeably less common. Somewhat more than half the biology teachers were using workbooks. There was wide use of supplementary reading and projects to provide for individual differences. The average teacher can

hardly avoid using more varied methods when textbooks and workbooks suggest them.

In the upper level courses, too, we find a great variety of teaching plans. Here and there botany and zoology are taught with laboratory and recitation separate and the older type of notebooks and examinations. Advanced biology courses may follow the Morrison plan or approach college type courses with lectures and laboratory work. In isolated instances, the most progressive student-teacher course planning goes on.

The biological parts of general science courses in the 7th, 8th, and 9th grades have gone through much the same changes as the biology courses, but were probably quicker to respond to new influences. In general, less laboratory work is done in these courses than in biology. The better general science laboratories are organized and equipped as adaptable workrooms for the study of science, but many classes meet in ordinary classrooms or in rooms planned for the traditional work in biology or one of the physical sciences.

In the elementary grades, two extremes of procedure have developed with the gradual introduction of science courses which has been going on since the early 1930's. Where teachers were capable and energetic, they have learned what amounts to a "cooperative unit plan" of teaching science material with less rigid procedure and shorter units. The classroom has work tables where experiments and exhibits develop and bulletin boards for pupils' drawings and pictures from many sources. The pupils obtain information by all sorts of methods, bring it to class and use it for oral and written work. At the opposite extreme are those classes which are really not taught by a new plan at all, but by the "reading method" transferred to the use of the science readers and textbooks which have been introduced by outside authority or because of a desire to "keep-up-to-date."

Having surveyed the development in teaching plans, we may consider briefly a few devices which have appeared or have been incorporated into biology teaching. The first of these was the objective test which ran through the educational world like

wildfire in the early 1920's and has since come into equilibrium with the older essay examinations. Some standardized objective tests in biology appeared as early as 1921. The Ruch-Crossman Biology Test and Pressey vocabulary tests appears in 1924 and both are still published although more recent tests are usually employed. Since that time standardized objective examinations have been used almost universally for comparisons between schools and between groups in pedagogical research. Where teachers use published instructional or unit tests they are invariably objective or short answer examinations.

During the 1930's the evaluation staff of the "eight-year study," conducted by the Progressive Education Association, developed a number of objective tests designed to measure growth in the ability to think "scientifically" in applying principles, interpreting data, etc., in biological areas as well as in other fields.[42] Similar tests were prepared for use with veterans of World War II who wished to return to school at a higher level than when they left.

The motion pictures entered biology classes about the same time as objective tests or a little later. By the late 1920's the "movies" had become significant enough in education that Wood and Freeman conducted an extensive study to measure their effectiveness.[47] Of ten science films used, two were on biological subjects. The results showed a noticeable improvement when pictures were shown in place of an equal amount of time devoted to the usual kind of study or teaching. In 1933 Rulon published his well-known volume, *The Sound Motion Picture in Science Teaching.*[40]

The motion picture, with or without sound, has become one of the most effective means of helping students as well as research workers study some of the activities of living things which are not easily observed. Nothing can rival their value for showing activities of cells and protoplasm, as in cell division, and the activities of animals which can seldom be observed for any adequate length of time by the average person. The animated diagrams which the motion picture makes possible are also unique as teaching devices. However, the cost and other

practical difficulties that arise in making use of films in biology instruction prevent their frequent use in many cases. Survey of a representative sample of schools in Minnesota in 1946-47 showed that less than one-half the biology teachers had possession or use of a motion picture projector.[3] Where a projector was available, the teacher used it, on the average, ten times a year. The number of teaching films available is still growing, but many of those produced specifically for teaching purposes are not well adapted to the unit method of study. Instead of helping the student make observations which he would be unable to make for himself and then permitting him to assimilate the knowledge he has gained, a large number of films attempt to substitute themselves for the teacher and present a lecture-demonstration of a whole unit in ten or twelve minutes. However, there exists today a wealth of significant and useful films, many of them produced by large corporations for public relations purposes and available at very low cost.

The standard lantern slide has practically disappeared from biology classrooms. About the time that the motion picture entered the educational field, 35 millimeter film strip or slide film began to be produced. It made way quite slowly until the Second World War when it was widely used for instruction in the armed forces. For some types of instruction, experiments have shown that it is just as effective as motion pictures and much less expensive and less difficult to use. Therefore, for certain subjects, some local visual aid centers are buying slide films rather than motion picture films.

Color film transparencies which appeared during the late 1930's have also tended to help crowd out standard lantern slides. With this film in the popular 35 millimeter candid camera, teachers have been able to make their own colored slides that far surpassed any expensive hand-colored slides. Soon after the color film appeared, the biological supply companies began to offer a good selection of 2 x 2-inch color slides. A wealth of such material is now available and is still increasing.

During the last twenty years, and especially during the last ten years, the radio has become a significant tool for biology

education. Health programs and the biography and history of biological science have been presented with increasing skill and art. Very few of these programs are received directly in the classroom because few rooms have receivers and because the time of the broadcast cannot be controlled. However, they do serve to increase the biological information and appreciation of the country at large, and transcriptions bring the better programs to a few classes. Teaching through transcriptions may well become more common as local libraries can be built up.

World War II emphasized the importance of finding and training young people who have high ability in biology. Scholarships were provided by a large corporation and a branch of Science Service was organized to carry on a nation-wide search for the most promising scientists. Along with this search there developed a move to encourage the organization of science clubs and to induce teachers to locate and encourage the growth of boys and girls with special capacities in science.

What changes in teaching may we anticipate in the coming years? That depends in part on the financial support which schools receive. The developments and research in methods which have gone on during the past thirty years point the way to the improvement of biology teaching; more capable and inspiring teachers who can lead students to participate actively in their own development; lower teaching loads so that there is time to find and guide promising young scientists as well as teach the best of biology to those who will not be scientists or not even go to college; better equipment and better libraries for good, all-around teaching. All these changes call for more generous financial support of education than has been given in the past. Unless there is a marked increase in funds, we may count on the continued entrance into our biology classes of teachers who have grown up in courses taught by the more flexible and varied methods, teachers who know the possibilities of motion pictures and are not afraid to use them along with slide films and colored slides, teachers who through personal experience know the greater self-direction and responsibility that comes through cooperative planning. Thus the gradual improvement of instruction should continue.

Development of Research in Science Teaching

In 1917, Twiss published the first widely-used general book on the teaching of science. In his preface, Twiss says of his book, "It attempts to show in a concrete and practical way how the findings of modern experimental and educational psychology may be applied to science teaching."[43] Yet the book refers to no research to indicate what science should be taught or how best to teach it. Of course, the main reason is that almost no useful research studies were available. Before 1917, only about nine had been reported, four in methods of teaching and five in curriculum, most of the latter being at the level of the elementary school. (Six of the nine dealt at least in part with biological content.)

By 1926, Curtis was able to summarize seventy different learning and curricular studies which were well known and of quality to justify their inclusion in his first digest.[18] Five years later, in preparing his second digest, Curtis, with the cooperation of the forty-two members of the National Association for Research in Science Teaching, prepared a "huge bibliography" and, from later suggestions, "a second bibliography almost as long as the first."[19] Most of these studies had been reported during the five year period. From the two bibliographies, with the help of members of the NARST, Curtis selected 92 research studies worthy of inclusion and more than 150 others good enough to be listed in supplementary bibliographies. The abundance of research made the selections for the third digest in 1939 equally difficult.[20]

Twenty-two years after the appearance of Professor Twiss' highly respected book, Victor H. Noll published a book, *The Teaching of Science in Elementary and Secondary Schools,* which presents a striking contrast.[32] Every appropriate part of Noll's discussion is supported by carefully selected research. Many other books and reports prepared before and after Noll's volume are similarly documented, yet, as in any other science, many problems remain to be solved in the second half of the century. What lines of study and what trends are observable in the research of the first half century?

For this account, the research studies are considered in two

groups, those that compare methods of teaching and learning (usually by means of more or less accurately controlled experiments), and those which in some way attempt to gather information as to what should be taught, at what level it should be taught, or how it should be organized. Studies of aims have been assigned to the second category.

The earliest study of teaching methods included in the Curtis digest of 1926 was one made by J. P. Gilbert in 1909-10 with a class of zoology students at the academy of the University of Illinois. He divided the class into two sections on the basis of sex, age, and various social factors. In one section he emphasized the "cultural and disciplinary" aspects of zoology while in the other he taught the same basic material but emphasized the "economic aspects," the helpful and injurious effects of animals. Essay and practical tests as well as personal observations of student interest provided data for comparing results.[18] (These results were uniformly favorable to the "economic" approach.)

If we accept Curtis' decision that this was a study of the effect of methods of teaching on learning, it initiated a line of varied research which is still bearing fruit. Other studies were reported at two-year intervals until 1916. The one for 1912 was Mayman's investigation for a Ph.D. thesis at Columbia University. It was clearly a comparison of methods, "book," "lecture," "experiment," and "experiment-note-book," in elementary science for the 7th and 8th grades.[18] The first use of standardized objective tests in chemistry for measuring results was reported in 1922.[18] (Note, however, that a considerable amount of research must have gone into the preparation and standardization of the Power's chemistry test used at that time.)

Cunningham, in 1920, used a group intelligence test in setting up his control groups, but did not use objective tests for results. Cunningham's study with 25 high school sophomores in a biology class initiated the famous series of investigations of demonstration versus individual laboratory. Cunningham himself summarized nearly forty such studies in 1946, eight of them for Master's theses and six for Doctor's theses.[17] He showed that

the problem arose out of the crowding of classes, the high cost of science instruction, practical difficulties in scheduling double periods, and the enthusiasm for developing a science of education. These same influences are still at work, and the comparisons of laboratory work with demonstrations continue to appear, a considerable number of them at the college level.

Another series of investigations which, in science, have been somewhat less numerous is the comparison of long-time assignment plans of teaching with the traditional daily-assignment-recitation plan. One of the earliest of these was reported by Cunningham in 1922. They increased in number as Morrison's influence spread. In recent years there has been a tendency to include more of the pupil-teacher planning factor in such comparisons in the attempt to discover whether equal or almost equal gains in knowledge can be made while attaining more change in ability to think and in scientific attitudes of students.

Types of pupil activities have come in for their share of attention. Early investigations (1916, 1927) studied the effects of representative drawings as opposed to analytical drawings of apparatus and biological materials and of inking biological drawings.[19] Later studies tested suspicions that the traditional requirements of many detailed drawings and formal write-ups were no more effective than less laborious forms of student reactions to laboratory work.

The results of these studies together with the recent emphasis on teaching scientific thinking and developing desired attitudes and on pupil-teacher planning has shifted the emphasis away from such artificial forms of pupil activity.

Visual aids are so important to science that they have been a fruitful subject of research. Do pupils learn more from motion pictures or from an equal amount of time spent in other ways? Are sound pictures better than silent pictures? How can one help pupils get the most out of pictures? When and where should they be shown? Are slide films as good as movies? Is microprojection equal to or better than individual use of microscopes? How about models as compared with the study of the real specimens? This type of investigation was initiated in the

last 1920's and is still going on. It produces results which quickly modify the practice of up-to-date teachers.

Development of teaching techniques and tests for the various aspects of scientific thinking and for scientific attitude began in the 1920's with the work of men like Downing and Curtis. During the 1930's, the "eight year experiment" of the Progressive Education Association greatly stimulated such studies.[42] In recent years evidence has accumulated that the results that have been claimed for "disciplinary" and indirect methods of teaching science do not exist, to develop ability to think with scientific data, to dispel superstition and develop self-direction, the methods of teaching must be especially planned to lead to these ends. Much research effort has recently been given and will continue to be given to testing the various methods that are invented for attaining such ends as over against the study of methods of gaining information and mastering principles which were emphasized earlier.

A second significant development in evaluation has come during the last 15 years. A number of methods of investigation have been worked out and used for measuring and recording pupil behavior without the use of paper and pencil or "practical" laboratory tests. In connection with the elementary school, West (1937),[46] Urban (1943),[45] and Hill (1946)[25] have made significant contributions. Bingham (1939) did similar work at the secondary level.[8]

With the availability of such techniques for evaluating behavior, more accurate investigations of teaching methods in the elementary school became possible. Studies of method below the seventh grade were notable for their scarcity before 1940, partly because of the incidental and more natural methods of teaching employed and partly because the usual objective tests were not suitable for use with the younger children. Science in the grades is becoming more general, well-trained teachers are increasing in number and, with suitable evaluation methods available, we may expect the studies of method there to continue. The direct evaluation of behavior can also be used in connection with objective tests of thinking and attitudes to improve teaching at the higher levels.

The problem of what we should teach is fully as troublesome as the problem of how we should teach and, of course, it is a prior problem. The volume of "curricular" studies has been even greater than that of the methods or learning studies. However, we are more inclined to question the soundness of their results because they can seldom be set up in the form of controlled experiments; they are more often statistical studies. And, what is more, they have very often been statistical studies of opinions.

The very earliest curriculum study digested by Curtis was Gilbert H. Trafton's investigation of the interests of elementary children, first reported in 1904.[18] Other studies of children's interests by Mau and Downing followed in 1912.[18] This line of investigation has produced occasional studies ever since with an increased number during the last twelve years. The later interest studies have attempted to correct defects in the earlier ones and to identify changes produced by changing conditions. The conscious aims and objectives in science teaching grow out of the philosophies of curriculum makers and teachers and out of the social forces that play upon them. Thus, basically, they are not subject to scientific investigation. However, one may use questionnaires and analyses in an attempt to find out what aims are most commonly held and how they change from time to time. A moderate number of studies have attempted to do this.

In 1909, George W. Hunter began a series of questionnaire studies of aims which continued from time to time until 1943.[26,27] Other significant surveys and analyses of objectives have been common.

Probably the largest number of curriculum investigations are the ones which attempt to select or evaluate items for a science curriculum in some objective manner. There is a long line of analyses of textbooks and courses of study, for terms, topics, principles, and concepts. An equal or greater number of researchers have made surveys to find what teachers teach or believe should be taught. In the past twelve years a number of summarizing studies have appeared. In 1938, Curtis published a report of one hundred analyses of vocabularies to climax a series that began in 1918.[21] The study of biology in the public

press as a basis of the needs of citizens was initiated in 1923 by Finley and Caldwell.[22] The series of twelve significant investigations was summarized in 1945 by Martin who added a considerable amount of his own data.[28] As another part of his Doctor's study, Martin had drawn together in a major study the biology principles most important for high school and college and added data from five major studies published during the years 1932 to 1936.[30]

Surveys of general education courses in colleges signal the development of science education there. Many studies of less numerous types are contributing to the development of a science curriculum: current superstitions and misconceptions; difficulty of principles and concepts at different grade levels; history of nature study; history of high school biology; improved tests. Recent summaries of research in science teaching indicate that the number of studies has declined somewhat since the outbreak of World War II. However, the average quality has risen, and improved procedures are being worked out for defining the needs of students and for serving them.[39]

Reports of committees at the 1948 meeting of the National Association for Research in Science Teaching are probably our best indication of the contributions which research in science teaching will be asked to make in the coming years.[38] These reports indicate that one of the major problems is to work out an integrated curriculum that meets the needs of boys and girls from the early elementary years into the college, and that is fitted to their interests and abilities at each level without such overlapping and repetition such as now exists. This problem must be attacked at a multitude of points. To put such a program into effect we need able and well-trained teachers. No one seems yet to have worked out a way of attracting a sufficient number of good teachers into the profession or of deciding what kind of training in science is best for them. In addition to these two major areas much work remains to be done in keeping us posted about the current science teaching situation, in working out the best practical kind of science rooms, in finding the most effective ways of using the teaching devices

we have, in identifying and encouraging talented students, in developing better tests of all kinds.

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The Physical Sciences

It is a difficult assignment to describe accurately what has occurred in the physical sciences for the past fifty years. It is possible to give, with some degree of accuracy, the changes in enrollment, the courses offered, and to some extent the methods of teaching that were in use. However, the opinions of teachers, the attitudes of pupils, and the results of teaching must be based largely on opinion or conjecture. It has not been possible to find any thorough evaluation of what pupils accomplished in their science courses.

It is evident that three reports have had a significant influence in determining the courses that have been offered and also the philosophy and methods of teaching that have been in use.

For convenience, the first period may be considered as extending from 1900 to 1920. The results of the thinking and teaching of this period are well summarized in the report[38] *Reorganization of Science in Secondary Schools,* U. S. Bureau of Education, Bulletin No. 26. Dr. O. W. Caldwell was chairman of the committee which made this report.

The second period extends from 1920 to 1932. The report of the National Society for the Study of Education,[25] Thirty-first Yearbook, Part I, *A Program for Science Teaching* with Dr. S. R.

Powers as Committee chairman challenged much of the content and many of the methods that were in use in this period and gave recommendations for significant changes for the future.

The third period extends from 1932 to the present. Many valuable reports and bulletins were issued in this period. Probably the three most significant reports are—*Purposes of Education in American Democracy*[7] by the Educational Policies Commission of the National Education Association, *Science in General Education*[39] by the Progressive Education Association (1935), and *Science Education in American Schools,*[25] the Forty-sixth Yearbook of the National Society for the Study of Education (1947).

It is not to be assumed that all science teachers agree with the summaries and digests given in these reports or with the suggested recommendations. However, the reports do give a fairly good summary of the thinking and planning which was going on in our schools. The large number of committee reports and publications in this period is evidence of the serious thought given to methods of improving our science education program.

Period 1900 to 1900

In the period from 1900 to 1920, changes were not sudden nor abrupt; they were gradual. Many changes that were observable in this period had their origins before 1900. Probably the most significant changes in this period were:

1. The rapid increase in the number of pupils enrolled in the secondary schools.
2. The increase in number of subjects offered such as music, industrial arts, commercial subjects, agriculture, and home economics.
3. The rapid decline in percentage enrollment in the physical and biological sciences as well as in mathematics and certain other established subjects.

According to the report of the United States Department of the Interior, Office of Education,[39] *Offerings and Registrations*

for High School Subjects (1933-34), the high school population increased from 519,296 in 1900 to 2,155,460 in 1922. In the same period the number of students enrolled in astronomy decreased from 14,435 to 1,474, or a decrease in percentage enrollment from 2.78 to 0.07. In geology the enrollment decreased from 18,743 students to 3,520, or a decrease in percentage enrollment from 3.61 to 0.16. In physical geography the enrollment decreased from 121,335 to 92,146, or a decrease in percentage enrollment from 23.37 to 4.28. In physics the enrollment increased from 98,896 to 192,380, with a decrease in percentage enrollment from 19.04 to 8.93. The enrollment in chemistry increased from 40,084 to 159,413, with a slight increase in percentage enrollment from 7.22 to 7.40. The percentage enrollment in general science was not given in 1900. In 1922 the enrollment was 130,728 and a percentage enrollment of 6.06. It should be understood that these enrollments and percentages are only approximately correct. There was no accurate method of reporting enrollments in this period.

Previous to 1900 the dominant purpose of secondary school science was to prepare students for the colleges and for the professions.[36,9] College entrance requirements were the dominating influence in determining what was taught in the secondary schools. From the best available data, the approximate percentage enrollment in 1900 of pupils of secondary school age in secondary schools was twenty percent. At present it is believed to be over eighty percent.

From 1900 to 1920, there was an increasing number of students in high school who did not plan to go to college. But our courses in science in this period did not provide adequately for this large number who did not plan to go to college. This statement is justified by the rapid decline in the enrollment in the subjects taught in the first two years of the high school, namely, astronomy, geology, and physical geography, as well as in botany, zoology, and physiology. The number of students who left school while in the 9th and 10th grades was evidence of the unsatisfactory courses offered in these two years. It is not meant that these subjects are not practical and cannot be

taught in a functional way, but evidently they were not taught that way.

In this period there was a tendency to offer semester courses in many different subjects such as astronomy, geology, physical geography, botany, zoology, and physiology in the first two years of the high school. It was not possible for pupils to take all of these courses with the result that students did not have the opportunity to have courses which gave them a background of understanding of the sciences. Furthermore these courses became formal with emphasis on structure and identification rather than practical applications, functions, and understanding.

In an effort to remedy the unsatisfactory conditions in science education a committee of the Central Association of Science and Mathematics Teachers with Dr. O. W. Caldwell as Chairman recommended in 1913 that general science be offered in the 9th grade, biology in the 10th grade, and chemistry and physics in the 11th and 12th grades.[34(m)] This report was published in *School Science and Mathematics,* Volume 14, 166-188. The Committee on Reorganization of Science in Secondary Schools made a similar recommendation in 1920. These recommendations, if followed, would have remedied the criticisms made of the science courses offered in the first two years of the high school, and would also have given students not going to college better preparation for living.

In this period the main objective was formal discipline. The second was the teaching of facts and principles. The third was college preparation. Some emphasis was given to skills. Very little importance was attached to scientific method, scientific attitudes, appreciation, or the social implications of science. Gradually less emphasis was given to dogma, superstition, and magic, and gradually more to getting answers to problems through demonstrations and experiments.

In making a survey of the articles in *School Science and Mathematics* magazine and the programs of the meetings of the Central Association of Science and Mathematics Teachers for this period, it is found that the persons active in promoting the bulletins and reports previously mentioned were also active

and influential members of the Association. It is also evident from such a survey that the science teachers in the Association were interested in discussing the problems of science education, with the result that many worthwhile recommendations in courses and methods were made.

Period 1920-1932

In the second period 1920-32 the high school enrollment continued to increase rapidly. More students were enrolled in the science courses such as physics, chemistry, biology, and general science. The enrollment in physical geography decreased slightly. In general, most of the schools were offering general science, biology, chemistry, and physics as a four year sequence of courses for the senior high school, grades 9 to 12 inclusive. Teachers were giving more emphasis to the teaching of scientific thinking and to a better understanding of the scientific method.[6] Considerable attention was given to the development of scientific attitudes. More and more scientific knowledge was being taught with an increased emphasis on practical applications.

Unfortunately the controversy over the demonstration versus laboratory method of teaching occurred during this period.[6] There need not be any controversy as to which is the best method. Both are needed. In some cases the demonstration method is sufficient. In other cases the laboratory is needed. In the author's estimation, this controversy has done much to make science a textbook study with but a very few demonstrations and no laboratory activities.

For immediate results, the demonstration method appeared better for teaching facts while the laboratory method gave better results when tested at later periods. What good science teacher claims the primary purpose of the laboratory is to teach facts?

It is true the laboratory activities were made too formal in many schools. That was poor teaching, and not necessarily a criticism of the laboratory method.

Unfortunately the depression occurred about the time the re-

sults of these investigations were becoming known. Administrators had a good excuse to reduce budgets for laboratory materials, and in many new schools being built the provision for laboratories was sharply reduced.

The rapid increase in the high school enrollment made the necessity of providing for individual differences more apparent. In this period we find much more emphasis given to the organization of subject matter as illustrated by the Morrison Unit Plan,[21] the Contract Plan,[20] and the ability grouping plan. Teachers were beginning to study their own methods of teaching and were organizing units of instruction which would adapt subject matter to the needs and interests of students with a wide range of mental abilities. It was also the beginning of the organization of textbooks in science on the unit plan.

Also during this period classes became larger and the teaching load heavier. This was caused by the increased number of pupils and at the latter part of the period by a decrease in funds. Neither the increase in size of classes nor the heavier teaching load helped in improving science instruction. It made for more textbook teaching and less laboratory activity.

Many of the generally accepted statements of psychologists were being questioned. The claims for value of formal discipline, the transfer of training, and the laws of learning were the result of logical reasoning and were not based on the results of experimentation. As a result, schools of experimental psychology were developing. The former claims for the values of science instruction were no longer accepted and were questioned by educational authorities. As a result, much serious consideration was being given to the objectives, purposes, and outcomes of science education.

The Yearbook,[21] *A Program of Science Teaching*, gave emphasis and importance to science in a general or liberal education. To quote from the report: "In a program of general or liberal education those truths which are the foundation of our social order and those methods which may be effectively used to reveal truth must be given prominence in the curriculum.

In this analysis, values are considered under two headings:

1. Those values which arise from the direct use of the facts, principles, and generalizations of science in everyday life.
2. Those values which are secured consistently from the study of natural sciences through forming generalizations respecting methods and through forming generalizations from which scientific attitudes may reasonably be expected to develop"

This report gave considerable emphasis to the development of a continuous program in science from grades one to twelve and in the two first years of college. More physical science was added to science for the elementary school and a three year general science program was recommended for grades 7, 8, and 9. The complete program was to be based on a selected number of generalizations and principles. Simple concepts grow by the addition of new learning elements, and generalizations are related groups of simple learning elements. Learning was to be gradual and cumulative, and not sudden, or complete.

Some disagreed with the report because the content was logically organized and the principles selected would not necessarily meet the needs of children or be interesting to them. Furthermore the practical value of science was not given enough prominence.

The report did have much influence in the organization of courses of study, textbooks, and methods of teaching in the third period 1932-1950.

The rapid development of the junior high school movement influenced the teaching of science in grades 7, 8, and 9 by making it more practical to an increasingly large number of boys and girls.[6] The greatest value of the junior high school has been the keeping of students in school. This school was designed to be more exploratory in nature than preceding schools and this gave teachers an excellent opportunity of developing a three-year sequential program, but as a whole, science teachers did not meet the challenge.

In summary, it may be said that more and more science was

taught to a much larger number of pupils. Emphasis shifted from knowledge to what could be done with knowledge. Hence more emphasis was placed on scientific thinking, scientific attitudes, problem solving, and appreciation. Science was coming to be more important for boys and girls in their everyday living. Teaching emphasis was shifting away from knowledge for its own sake to knowledge for the sake of better living.

However, the increase in size of classes, a larger teaching load, relatively decreasing budgets, and the loss of many worthwhile laboratory activities and experimentation must be placed on the debit side. No teacher could be expected to teach effectively when the teaching load reached the proportions it did at the close of this period.

Period 1932 to 1950

In the third period 1932-1950, the number of pupils in high school continued to increase rapidly, and the needs of science education in a modern democratic society was being realized. Many new courses such as senior science, consumer science, health, conservation, safety, electronics, and aviation were introduced in many schools. This is evidence that science teachers were attempting to develop courses which would meet the needs of the modern cosmopolitan high school. Colleges were changing their programs to better meet the needs of science teachers.

In many of these new courses, there was too much talking about science without providing the facts and principles for understanding. Pupils were asked to correlate and integrate when they had not acquired the knowledge with which they could integrate or correlate.

In this period, we see the rapid growth and development of new organizations of science teachers and the publication of several magazines on science education. The Central Association of Science and Mathematics Teachers provided much help and influence through *School Science and Mathematics.* The National Association of Science Teachers published the *Science Teacher,* the National Association for Research in Science

Teaching published *Science Education*, and several local and district organizations published their own magazines. All of these organizations and publications have been one of the most influential factors in improving science instruction.

In this same period, many new textbooks were published. As a general rule, the textbooks had a better selected and better organized body of subject matter. They were better illustrated and more interesting and attractive to boys and girls. They also included valuable helps for students and teachers. For the busy teacher, workbooks and study guides were provided. Also, there were tests and other evaluation aids.

Many of the books included materials which would help pupils get a better understanding of the social implications of science. The textbooks in science kept pace with the changing philosophies of education.

In this same period, many new teaching aids, such as motion pictures, slides and films, models, charts, and new pieces of apparatus were produced. If used effectively, all of them could be valuable aids in improving science instruction.

Many teachers attempted to solve the urgent teaching problems in science through research, investigations, and study, and the results, if applied, should improve classroom instruction. Professor Francis D. Curtis contributed a valuable service by providing a summary of research in the three volumes, *Digests of Investigation in the Teaching of Science, Second Digest of Investigations in the Teaching of Science,* and *Third Digest of Investigations in the Teaching of Science.*[4]

Science Education also published many valuable research reports. There are hundreds of unpublished master's and doctor's theses which would provide valuable information if they could be made available.

The report by the Progressive Education Association, *Science in General Education,*[30] emphasized more functional teaching and the selection of content based on the needs of boys and girls. It also emphasized the necessity of more correlation of science with everyday problems of living.

The Forty-first Yearbook of the National Society for the Study

of Education,[27] *Science Education in American Schools,* gives a good digest and summary of science education from 1932 to 1947. It summarizes the development in the curriculum, organization, and selection of content, methods of teaching and evaluation for the elementary, junior, and senior high schools. Science education has followed the trends of education in general. More emphasis is placed on science as a means of accomplishing certain desired results than on the mastery of facts and principles. However, there is no decreased emphasis on the importance of scientific knowledge.

The list of objectives in the Forty-first Yearbook gives a good indication of the type of science education which will be most useful in the daily life of boys and girls.

The objectives given in the Forty-first Yearbook are these:

1. Functional information or facts.
2. Functional concepts.
3. Functional understanding of principles.
4. Instrumental skills.
5. Problem-solving skills.
6. Attitudes.
7. Appreciations.
8. Interests.

"Objectives here are conceived as directions of growth and not as final outcomes to be completely and perfectly attained. The learning process is held to be growth toward the objectives rather than one of complete attainment of any goal."

In the Chapter, Issues in the Teaching of Science, the committee has given answers to many of the questions raised by teachers in their daily teaching. Many good science teachers will not agree with the answers to these issues or to the recommendations offered. For example, the committee states that the forty-five minute period is long enough for good laboratory activities and that in the interests of economy, both of time and of money, it is desirable to perform more laboratory exercises by the demonstration than by the individual laboratory method. No attempt should be made to draw such conclusions without

first defining the needs and purposes of each method. There is no available evidence this has been done.

As a general summary, it may be said that the physical sciences have followed the changes in content, functions, purposes, and methods made in education as a whole. There is more emphasis on teaching boys and girls rather than subject matter as an aim in itself. There is a growing emphasis in teaching the social implications of science.

Physics

Physics was originally taught as natural philosophy. In 1901 Carhart and Chute in their textbook, *High School Physics*, included units on mechanics of solids, mechanics of fluids, sound, light, heat, and magnetism and electricity in that sequence. One-fourth of the book was devoted to the study of magnetism and electricity.

In 1922, in Dull's textbook *Modern Physics*, the units were mechanics of fluids, mechanics of solids, heat, sound, light, magnetism and electricity. In 1949, the same units are used in about the same sequence.

In the period from 1900 to 1950, physics textbooks have increased in size and quality of material to a point where it is doubtful if it is possible for pupils to master all of the content. The physics courses are highly organized, and there is almost unanimous agreement in the content included in the textbooks.

The modern textbook includes the new principles and facts which have been acquired, it is better illustrated, and contains many practical applications. The objectives have changed from formal discipline and college preparation to scientific methods, attitudes, and functions. There is also an increasing emphasis on knowledge and the purposes which this knowledge may serve.

Physics may be classed as a quantitative science.[16] It may easily be made the basis for much quantitative thinking. Many of the facts and principles may be obtained through laboratory measurements. It may also be made an exact science in many

instances. For this reason many educators believe a pupil needs a good background of mathematical undertakings to be a good student in physics. The more mathematics a student has had, the better prepared he will be for quantitative thinking.

The vocabulary in physics includes about 1900 new terms the average student will need to learn. Students have as much difficulty with words as they do with mathematics. All the mathematical calculations may be included in the four fundamental operations and simple square root.

Several attempts have been made to reorganize physics courses on the basis of functions, or problems, or units in which the content is better integrated with other sciences and better correlated with other subjects. Anything that will improve the teaching of physics is desirable. Whether the new methods of organization improve teaching remains to be proved.

Many schools have not been able to secure large enough budgets to develop laboratories in which all of the desirable types of activities may be performed. Approximately only one high school in ten is equipped for satisfactory laboratory activities. Many of the small schools have very little demonstration equipment and materials. For many schools, textbook teaching without demonstrations or laboratory activities is a common procedure.

In schools which have well equipped laboratories and teachers adequately trained in both content and methods, the enrollment in physics classes has been satisfactory and the results obtained have helped pupils to meet the needs of modern society.

General Science

Much of the history of general science has been included in the history of the physical sciences.[6,9] According to Taylor's study, The Extent and Adoption of Attitude Toward General Science, School and Society, IV, 179-86, there were at least three schools experimenting with courses in general science in

1900, one in Massachusetts, one in California, and one in Illinois. By 1909 there were only five schools in California and fifteen in Massachusetts offering such a course. By 1914, 223 schools in California and Massachusetts had introduced the course. In 1918, the growth had been rapid enough to be included in the U. S. Commissioner's report.

Probably the best summary of the purposes and need for general science was stated by J. C. Hanria, then principal of Oak Park High School. "It seems to me that the science teaching of the high schools was not well adapted to the capacity of the pupils and was not so conducted as to challenge and hold their interest and, further, that it lacked in the recognition of the psychology of youth and the ordinary principles of pedagogy, as well as in its definitions of relation to the real things of life. There seemed to me to be a necessity for working out some kind of primary or elementary course that should be simpler and better adapted to the age of the pupils both in content and in method of presentation and that should commend itself to them as being related to some other phases of life besides the machinery of schools.

"It seemed to me, also, that inasmuch as the phenomena of nature are presented to us unclassified, not grouped at all as physical, chemical, physiographical, biological, etc., and inasmuch as the interests of pupils in meeting the problems connected with these phenomena could not very well be confined to one subdivision of them, all hankerings being suppressed for investigation in other fields, that there ought to be a course that would peep into all of these directions, or, as I have many times expressed it, it seemed that a bird's-eye view of the field of natural science was a necessity for good pedagogical reasons before taking up what I have sometimes called the "toad's-eye view."[4]

The greatest drawback to the development of the general science program was the lack of qualified teachers. Most of the teachers had been trained as specialists and also they did not have the philosophy or point of view needed for the reorganization of subject matter which cut across several subject matter areas. In fact, the greatest opposition to the development

of the program came from teachers who were specialists in one field of subject matter.

The first textbooks in general science emphasized one area of subject matter such as physics, physiography, botany, or zoology. The first six textbooks published will help to illustrate the meaning of the above statement: Powell, *Introduction to Science,* 1911; Clock, *General Science,* 1912; Caldwell and Eikenberry, *Elements of General Science,* 1914; Snyder, *First Year Science,* 1914; Hessler, *First Year Science,* 1914; Clark, *Introduction to Science,* 1915.

Further, many of the textbooks were written by authors who had not taught the subject to boys and girls of the age who were enrolled in general science classes. The organization of content was the same as in the textbooks for special fields.

Gradually, as teachers became better trained both in breadth of content and in problems of curriculum construction and reorganization, the textbooks began to fulfill the original philosophy and purposes of general science. The content was based on the needs and interests of boys and girls. The improved unit organization helped students to get a better understanding of the general principles of science.

At present, the danger to general science is the too formal organization and selection of content. Textbooks are too often written to comply with certain courses of study rather than the practical applications of science and the science content pupils can learn.

Another cause for the slow development of the general science program was the lack of well equipped laboratories and types of laboratory activities which could be done by boys and girls and which would help them to learn the meaning of the scientific method and to acquire the scientific attitudes. Pupils need laboratory experiences, need to work with tools, materials, and supplies. They need to acquire skills and interests. Students who have the abilities to become good scientists should be discovered in general science. They are the students who should be encouraged to plan a continuous program in science in the senior high school.

Boys and girls can learn some phases of science from the

textbook, but they cannot become good scientists without laboratory experiences any more than a student can learn to play a musical instrument without an instrument, or a girl learn home economics without a kitchen or sewing room, or a boy do well in industrial arts without tools, lathes, etc. The lack of laboratories for general science cannot be attributed entirely to financial reasons. No doubt it is due to the fact that so many teachers believe a few demonstrations is all that is needed for good science instruction. The laboratory, including supplies and materials, need not cost more than instruments for the band or orchestra, or supplies and equipment for home economics or industrial arts.

The most urgent problem at present is the development of a three-year sequential program for grades 7, 8, and 9. We have several series of textbooks for these grades, but so far the difficulty has been to plan a program so that what is taught in grade 7 can be expanded in grades 8 and 9 without loss of interest or the feeling of duplication on the part of the students.

Physical Science

Many students will not be able to take more than one year of science in the senior high school. This is true for students in commercial education and some other specific courses.

Then, too, some educators believe that many students in the senior high school will profit more from a year's combined course of the physical sciences than from intensive study of one of the special sciences. In addition, some students may not have the mental ability to profit from the specialized courses. For the latter group, courses in consumer science or applied science or senior science are provided.

The attempt to combine courses is not new. A course which would be a combination of physics and chemistry was discussed at the meeting of the science section of the National Education Association at Denver in 1895. It was discussed as a "sandwiched" course in science.

There is not much scientific evidence to prove that the study

of a course which is a combination of all of the physical sciences is better for boys and girls in the senior high school than an intensive study of one science. The difficulty appears to be one of integration. Can pupils be expected to integrate satisfactorily before a satisfactory background of knowledge has been acquired? The only place integration can occur is in the pupil's mind and thinking.

There is no available information on the enrollment in these courses at the present time, and it is not possible to give any accurate estimate of the number of pupils enrolled, nor to say whether the enrollment is decreasing or increasing.

Chemistry

Examination of the past fifty years of the teaching of chemistry may lead to appreciation of the progress that has been made, of the problems encountered, and of the *status quo*—in short, the route we now are traveling. One will note that, in addition to the force of advances in chemical information, many forces outside the field of chemistry proper became involved from time to time and resulted in curriculum changes involving instruction in chemistry.

Chemistry originally found its way into the school curriculum as a result of the rapid growth of interest in chemical and scientific studies in the early nineteenth century. Prior to this there was no chance for such a subject to exist in the secondary school, for the Latin Grammar schools, which were first established in Boston in 1635, still maintained their purpose to develop boys capable of speaking, reading, and writing classical Latin correctly and fluently. The realization of this aim left no time for anything else. Hence these schools were impervious to the scientific development going on around them.

School Chemistry Previous to 1900

About 1750-1800, chemistry was first given in university medical schools by men trained in Europe or by their activities in some of the scientific societies of America. By 1800, logical gen-

eral chemistry was taught to seniors in arts courses of four American colleges and universities. With the expansion of knowledge of chemistry, the classification of parts of the subject into smaller units such as general, organic, qualitative, and quantitative, and, later the introduction of laboratory practice, elementary chemistry moved down by degrees to become a freshman course.

A wave of general interest in chemistry, aroused in part by the popular demonstration lectures delivered on the Lyceum platform and the results of practical university research, resulted in its following that general tendency for subjects of learning to move downward from college curriculums to those of the high schools. The economic value of chemical knowledge to persons destined for non-professional activities was another reason for beginning to teach chemistry to adolescents.

Academies came into existence in America during this time, and, as early as 1813, a chemistry class was being taught in one of them. The second high school in the United States, the Boston High School for Girls, opened in 1826, and immediately required chemistry as a third year subject. As other cities founded high schools, nearly all of them offered instruction in chemistry. An idea of the nature of the course given in one of the schools may be seen in an early announcement of the Oxford Female Academy in an advertisement in the Raleigh, N.C., *Register*, March 23, 1827, which said, "Since the commencement of the session, we have received a chemical philosophical apparatus, and now each recitation in Chemistry, Philosophy, and Astronomy is accompanied with a lecture and experiments, illustrating the principles of these sciences."

Liebig Influence

The laboratory may be traced to Liebig, and the text book pattern to Wohler. The problem of equipment was usually a difficult one. Apparatus that could not be borrowed from the druggist had to be imported from England at great expense. Although American teachers had an appreciation of the laboratory method introduced by Justus von Liebig at the University

of Geissen early in the nineteenth century, little or no use was made of the laboratory by students. The instructors sometimes advocated, however, that "pupils" be required to handle the apparatus in order that they might better understand the experiments, later to be performed by the instructor." Popular usage of Professor Will's English translation (published in 1846) of Liebig's course in analytical chemistry resulted in the laboratory becoming the center of instruction, and lectures or explanations were few. The pupils were subjected to the use of Liebig's "cook-book," as it came to be called, from which they learned principally how to follow directions.

This influence of the laboratory-for-students movement was slight in the American institutions, however. As late as 1872, there were only six institutions of higher learning so equipped, according to Charles Eliot. This state of affairs was explained by Frank Clarke as due to cost and to the difficulty of finding trained teachers with whom science was not subordinate to other things. He advocated realization of forty to fifty per cent economy by taking advantage of the privilege, granted to schools and colleges by congress, of importing apparatus duty free directly, instead of patronizing local dealers.

It turned out, during the nineteenth century, that the application aspects of chemistry instruction waned in spite of the teachers' interest in the practical.[28] The introduction of chemistry into the high school program was originally justified by the assumption that it would contribute something to the pupils' mental development in the way of discipline and knowledge. Consequently, chemistry was presented largely as a pure science. The course would center around the preparation of a few gases, and as soon as possible would endeavour to train the pupil in qualitative and quantitative analysis. Illustrative and descriptive matter was conspicuously absent from the presentation of theories and principles.

This course continued to be the offering in elementary chemistry in both high schools and colleges in America until about 1890. Any progress in the teaching of elementary chemistry that had been made up to this time was made in England following

proposals of Professor Armstrong (1889) to teach chemistry to younger pupils, to stress method at the expense of complete coverage of any prescribed course, to put the pupil in the place of the discoverer. In this country, William T. Harris[11] made observations first issued in his 1871 Board of Education Report to the effect that not everything can be taught and that therefore method rather than quantity should be stressed. Since colleges and preparatory schools were doing parallel work and to the same extent and in the same way, in 1880, Clarke advised that the colleges ought to do higher work. By 1885, high schools offering chemistry had the laboratories and a tedious cook-book type of work which left much to be desired in the way of developing the pupil's ability to work and think for himself. It was mechanical and demoralizing. This was rebellion against applied analytical chemistry. Clarke claimed that secondary school science should be general instruction rather than special. "The attempt is too often made to teach applied science where there are no foundations of science to apply. . . . Fundamental ideas, conservation of energy, correlation of forces, conceptions of atoms and molecules, etc., ought to be clearly inculcated. . . . In chemistry it is better to concentrate upon the inorganic portion of the science, leaving the complicated organic side for more advanced study."

By this time the application aspects of chemistry in high school instruction had played out. The college preparatory notion had grown to predominance following the adoption of a system of accrediting begun at the University of Michigan in 1871. When Harvard University decided to accept chemistry credit in 1888, the conditions were prescribed in effect by Harvard Professor Cook's plan, "Laboratory Practice," for teaching elementary chemistry. This included new ideals of developing a collaboration of a classroom course and a laboratory course in chemistry, minimizing analysis applications. This plan increased in influence until World War I.

Position of Chemistry in the High School Curriculum

In 1893, the Report of the Committee of Ten of the National Education Association recommended that chemistry should pre-

cede physics and physics should be in the fourth year in high school, because physics needed more mathematics. The 1899 Committee of the National Education Association on College Entrance Requirements recommended the last year of high school for chemistry. The University of the State of New York Regents also recommended the last year of high school for chemistry. While reasons were argued pro and con, it may be noted that the latest mental discipline had strategical as well as psychological motive. There were so many three year high schools at the time that the "last year" recommendation provided greater chances of chemistry being studied and of being studied by the most mature students in the given high school. Alexander Smith[35] dwelt long and eloquently upon this matter, particularly establishing that "observations in chemistry are a study of physical properties."

Major Factors 1900-1949

Smith summarized the 1902 condition of chemical instruction as follows. He noted its struggle for admission into schools and its struggle for rank. He observed that the latter was won by a moral victory, the opponents defeated, but "it may be doubted whether they are convinced." Some of the difficulties with which chemistry contended were these: (1) There was a lack of continuous instruction in science courses running throughout every year of school work. However, "this was being remedied." (2) Defects in training chemistry teachers were chiefly practices that were too dogmatic and unscientific, and too much emphasis on qualitative and quantitative chemistry. (3) Lack of unity in aim and method was ". . . so notorious that when, a few years ago, a set of educational conferences was called at Columbia University, no conference on science was held. It was considered that the opinions of its advocates were so unsettled that the colleges had no basis on which to fix definite requirements in science at all." (4) The intrinsic difficulty of the science, quoting Professor Cooley, is that "Phenomena are the symbols in which truths are written, but phenomena abount in superficial likeness, obscure differences, and deceptive analogies. A correct translation of this language requires keen perception, accurate judg-

ment, and crystalline forms of expression." (5) Much of the school work done in chemistry was trivial in nature. (6) Other hindrances were that schools graduated pupils who had neglected the science. To appease clamour for representation of science work in the curriculum, classes in chemistry were assigned to unprepared teachers. Authorities were prone to load four or five sciences on one teacher. The day was cut up mechanically without regard to needs.

Articulation of school and college chemistry was still a problem. Some colleges were offering two independent courses to freshmen. President Eliot of Harvard University said, "It would be a pity if we could not adapt our courses in college to any good teaching in the schools."

Functional Psychology and Changing World Concept

At the turn of the century, one could witness the appearance of functional psychology with its "is for" contrasting with the "is" of other schools of psychology. The nucleus of this functionalism is usually indicated as the teaching of John Dewey. Associated with Dewey at the University of Chicago and primarily credited with the founding of functional psychology was James Rowland Angell. James McKeen Cattell and E. L. Thorndike at Columbia University, and G. T. Ladd at Yale University were also leading figures in the development of this psychology which was destined to take hold of public education generally for the duration of the period under consideration. The validity of this contention for chemistry instruction will become evident as one observes details of the period. Let us admit here that only some highlights of history pertinent to chemistry teaching may share the space allowed.

Central Association of Science and Mathematics Teachers

Laboratory instruction was coming to be appreciated. Angell, who went to Chicago University in 1895, was to have his laboratory for the development of experimental psychology. Others sought to explore teaching in this fashion. To insure the continuance of this possibility, among other things, five sections, in-

cluding biology, chemistry, earth science, mathematics, and physics, were made functional units when the Central Association of Science and Mathematics Teachers was organized in April, 1903. "The Association, together with its official Journal, has accomplished more than any other agency in raising the standard of secondary science and mathematics teaching."[34(j)] Precedents for this sort of organization were abundant in the last twenty years of the nineteenth century. Evidence of the development of spirit and influence of the organization in different places appeared frequently. For example, a member of the chemistry section, "Frank B. Wade, of Shortridge High School, Indianapolis, Indiana, gave an illustrated talk on 'Precious Stones' at the sixtieth annual meeting of the Indiana Association of Science and Mathematics Teachers held in Marion on March 10 and 11, 1911." "The Northwestern Ohio Center of the Central Association of Science and Mathematics Teachers was organized in Toledo in March. The first annual meeting was held at Central High School on April 29, 1911." J. O. Frank's "Best List of Reference Books for $100.00" states that "School Science and Mathematics is best where only one periodical can be obtained."[10]

High School Chemistry Teaching Symposium

The functional psychology movement was enhanced by the budding vocational education movement in the first decade of the twentieth century. The stand of chemistry teachers in the face of current events was clarified by a Symposium on the Purpose and Organization of Chemistry Teaching in the High Schools conducted by School Science and Mathematics in 1908-1910. The dominant outcome expressed was opposition to the notion that high school chemistry was preparation for college and to the notion that it was vocational. It purported to be practical, emphasizing applications fitting the high school pupil's everyday life. Many of the expressions of aims and purposes of chemistry instruction advocated as a result of this symposium, with the significant exception of teacher training, were accepted common practice by 1917, if we can rely on the results of a

questionnaire. Judging by the Association Chemistry Section meeting activities, the minimizing of instruction in chemical theory and principles to allow time for illustration and applications to everyday life was bitterly resisted for some time after 1910.

Improvement of Equipment

Whereas the U. S. Bureau of Education was advising teachers how to import apparatus from England and Bohemia tariff free in 1880, and home made apparatus, if any, was the rule in 1914, the situation which had been slowly changing for the better was suddenly improved by the production of pyrex. War time growth of the chemical industry in America forced the development of equipment in this country. The writer, in January, 1949, asked ten chemistry teachers, selected because each had taught for nearly fifty years, "What do you think has been the most outstanding change in chemistry instruction so far this century?" The recurring answer was "Equipment has been improved and made more available."

Impact of Increase in School Population

With the secondary school population doubling each decade, with this growth definitely out of proportion to increase in teachers and facilities, difficult situations naturally appeared. Individual differences demanded attention as standards were applied. Various purported analyses of the difficulties at first resulted in unsatisfactory classification of pupils and subject matter.

Those who failed were called laggards and a host of other names. The cost of repeating courses became apparent. Segregation by sex was tried.[34(e),(h),(i)] Little schools tried it for science courses alone. Some of the larger school systems experimented by dividing an entire high school into two schools, one for the boys and one for the girls. In one instance, an attempt was made to make chemistry take on new appeal by using Ostwald's "*Die Schule der Chemie,*" a text book written in German, for the last part of the course. Bradbury criticized the dogmatic

uniformity of textbooks. Others were noting that the logical arrangement of the chemistry course makes it a mechanism that is "good" for the pupil, but for which the pupil, as he is not in on the secret, cannot see the reason. Use of visual aids (stereoptican) to describe practical applications was suggested to prevent the going to seed on theory. School Science and Mathematics took cognizance of the distinctions being made and created a new departmental editorship, entitled Research in Chemistry, and appointed Professor B. S. Hopkins as editor. The original departmental chemistry editorship continued in the hands of Frank B. Wade.

N. E. A. Cardinal Principles of Education

The statement of cardinal principles of education[14] in 1918 was one effort to give a social direction to education. Specific principles controlling reorganization of the teaching of chemistry stated that presentation must appeal the the pupil personally, selection of topics must be unhandicapped by traditional content of the course, and that isolation of topics should be hindered by organization in larger units. Certain topics naturally, cover wide fields, e.g., neutralization, hydrolysis, and oxidation. What laws and theories would be studied must evolve as generalizations justified by experimental data—as a device to explain things that the pupil is eager to understand. Likewise any chemical mathematics should evolve from laboratory situations. The teacher was urged to step into new character and go treasure hunting with his pupils in the laboratory.[33]

Acceptance of Principles

In the eastern states, the examinations of the College Entrance Examination Board and those of the Regents of the University of the State of New York retained memory requirements.[32] After a direct attack on the situation was made by local responsible administrators, a second study showed no improvement but rather more memory requirements. In the middle west, leaders at the close of the second decade of this century, called attention to the fact that present day authors have a tend-

ency to avoid definition of chemical fundamentals, whereas twenty-five years ago textbooks gave many definitions.[34(n)] Teacher-pupil contact in the laboratory with the teacher asking questions was highly recommended in place of relying on pupil notebook reports. The object became, not to teach chemistry,[34(l)] but to teach pupils how to learn. C. E. Osborne of Oak Park High School accepted the new spirit an demonstrated to an enthusiastic community.[34(n)] At the same time, another similar program was being carried on at the junior college level.[34(n)] Some teachers conceded that the reorganization proposal was probably theoretically correct, but called it impractical. On the Pacific coast, the spirit was exemplified by the action of the University of California in encouraging pupils to take high school chemistry and in that University's adoption of open book examinations to remove emphasis on mere memory work in general chemistry.[12] Such devices as project teaching and contract units appeared throughout the land as indications that teachers were observing interests of pupils as well as subject matter. The authors, Caldwell and Kingsley, said that the report was in the nature of a statement of what progressive science teachers had already accomplished, since it was the work of forty-seven science teachers working for over seven years.[34(n)]

Those who had observed the changing character of high school population as enrolments increased 711 percent while the total population increased 68 percent should have been the best prepared for the revelation of such studies as G. S. Counts' "The Selective Character of Secondary Education." The high schools were still quite selective in spite of the observed changes and adaptation.

World War I was in a large sense a chemical war. Chemical industry in the United States grew enormously. Evidences of interest of the chemical industry in chemical education appeared in the activities of the Chemical Foundation of New York City. It sponsored the study, Investment in Chemical Education in U. S. It sponsored publication of books in the field of applied chemistry. The American Chemical Society Committee on Chemical Education began publishing the *Journal of Chemical Education* in 1924.

Hanor Webb reported that discussion participants at early meetings of the American Chemical Society Division of Chemical Education were mostly college professors and industrial chemists. They noted that keeping an up-to-date acquaintance with chemistry would consist, among other activities, in selective reading from more than sixty chemical abstracts per day. They thought that a need of spreading knowledge already possessed surpassed the need of new discoveries. They supported *Chemical News Service* and a host of other publications projects. The committee published a *Standard Minimum Course in High School Chemistry*. Speaking for high school teachers, Margery S. Gillson pronounced it "too full for mastery in one year."

That school officials were more interested in social contributions of instruction in chemistry than in chemistry instruction itself was emphasized by Powers' compilation of objectives in 1925.[34(o)] This interest is sufficient to account for the brief duration of the market for subject matter tests in chemistry, which seemed to come to an abrupt end about this time. Bell (1917), Jones (1917), Powers (1911 and revisions), Rivett (1921), Glenn (1921), and Rich (1923) were among those interested social contributions of the subject. Text book authors generally provide unit tests as study aids.

During the remaining years of the twenties, efforts centered around adjustment of courses to fit the cardinal principles of education.[15] Meanwhile, in the lull of prosperity, school systems were standardizing furniture, equipment, and instruction.

Depression Crisis

"Life enrichment through participation in a democratic social order"[25] was an educational objective which received increasing emphasis and was responsible for lessened emphasis on science. Distribution rather than production was again declared to be a social problem. A demand existed for general science in addition to chemistry as such to satisfy the educational need of the increasing school population. The need of an adequate, definite theory of education found by Beauchamp, who analyzed thirty courses of study in chemistry, vintage of 1925-1932, indicated the timeliness of suggestions for keeping up to date. Kandel

noted this absence of a general aim for secondary education and advised provision for the slow maturing individuals in something other than "packages of equal value," his term for school credit units. With the increase of comprehensive social functionalism, the growing insecurity of subjects as organization patterns continued.[8] Notwithstanding, the per cent of total school enrollment in chemistry stood at seven per cent consistently from 1900 until the time of Efron's study in 1937. Chemistry was an essential part of general education.

Science and the Citizen

In peace and war, in general education and in special education, chemistry instruction can be functional. At the beginning of World War II there was an adequate, though not excessive, supply of chemists for essential and key positions. The situation was wholesome, because of the manner in which chemistry lent itself to adjustment in industry and education. Evidence of the intention of science leaders to make high school chemistry functional may be illustrated by the psychological preparations being made in 1944 for post war periods.[5,17] As the fighting part of the war ended, attention could turn to fundamentals, and to the teaching of a new school population, new in the sense that nerves of young people and returning veterans demanded understanding and changes of pace. One of the most promising of recurring suggestions for keeping up to date in modern general education, where instruction must be provided in chemistry for the so-called general pupils in addition to the college preparatory pupils, comes from both industry and schools.[1,2] This suggestion is to use laboratory, discussion, and other analysis of cases (history and method) to make the point clear and to enliven the subject. Wise selection of cases gives opportunity to consider the possible plurality of scientific methods, recognition of the continuing advance of the science, and allows adaptations for the fast, average, and slow pupil. It permits of administration in the small school or in the core subject curriculum school.[34(q)] Dead wood may be removed. Differentiation from special education, such as vocational education, and fuller

meaning of chemistry to our mode of life may evolve. Implications for the training of teachers involve training to think in terms of functional areas the boundaries of which are subject to change. At the same time, measurement and evaluation must be included in the best thought on aims and purposes.

Science in the Elementary School

Nature Study and not Elementary Science was the common name applied to the science for the elementary school child in 1900. The name Elementary Science or Elementary School Science, previously used, had been replaced by the name Nature Study.

The program of nature study, which had reached its peak in the period 1900-1910, had its basis in a philosophy of education no longer considered valid. The philosophy of education of that day evolved under the influence of the psychology of learning that believed that learning or mental development was serial and saltatory. Childhood was considered to be *the* age for memorizing and with age of adolescence came the ability to reason.

As a result of this psychology of learning the nature study of the day consisted of facts about objects in nature. "As nature study was first taught in the common schools, the idea was to try to introduce the child to the wonderful in nature. This was the prevailing notion of both teachers and authors of nature study books. Stories of curious and remarkable plants and animals were told to children or read to them. It was the marvelous that was intended to excite the curiosity of children. They were taught freakish or outlandish things, usually such as could seldom be seen by children. Among things read to them from science books were descriptions of Mammoth Cave, the big trees of California, the duckbill of Australia, icebergs and geysers."[18]

Around 1900 a new philosophic view of life and education emerged. This view has been variously described as experimentalism, pragmatism, or the new education. John Dewey played

no small part in the initiation and development of this school of thought. The publication in 1910 by Dewey of *How We Think* gave some form and direction to this philosophy of the new education.

The influence of this new education is revealed in the following statement: "Nature Study may be thought of in two senses. First, it may be considered part of a broad general development resulting from the combined influences of romanticism and the "new" education. Second, it may be thought of more specifically as a school program initiated and largely directed by Dr. Liberty Hyde Bailey and his associates at Cornell University."[34]

The nature study of the day had reference, not to the development of understandings concerning biological principles, but rather to the development of the love of nature. Its values were variously stated as utilitarian, moral, aesthetic, ethical, or religious. Pupils were to observe nature in all its glory and thus develop more completely the inner self.

"The aim of nature study as an educational process is to put the child in sympathy with his surroundings—with his own life. Its end is to educate him by means of the subjects within his own sphere. It seeks to quicken his sympathetic interest in the things about him, and thereby to energize his self-activity through which his life is enlarged, enriched, and vitalized. Its immediate value is to broaden knowledge, to cultivate interest in nature and man, to develop power of observation, to develop the power to compare, discriminate, and judge, to train the power of expression, and to make one resourceful. An incidental value of nature study is to inspire an appreciation of rural surroundings to give contentment to country life and to make farming a happier, more attractive, and more valuable calling. Nature study contributes much to right civic and moral training. It inspires kindness to God's creatures, gentle manners and a fine regard for the rights and well being of others. It gives a larger love of home and familiar scenes and a deep interest in men and things, which are the heart of good citizenship. In brief, it tends to adapt the child to his threefold environment, nature, man, God."[31]

Some educators of the day used the terms nature study and science synonymously. This, however, was not generally accepted. Wilbur S. Jackman, in an article, *Nature Study True to Life,* written in 1903, states, "Nature study true to life has existed with children before they enter school, since the creation of man. If we would hold it in the schools equally true to life, we must study the way nature teaches in this period and the way children learn. In their early years they learn because they love nature; if in after years they fail to learn, it is because they hate science. They surrender themselves unconditionally to nature, but with science they barter and make terms. Nature itself fascinates and leads; science too often repels and drives."[13]

The training of teachers in this area was also a problem of great concern. Lincoln M. Rutledge stated in 1904, concerning the teaching of nature study: "In nature teaching, seek first to be full of your subject and then to make your simple but really scientific treatment of it attractive to the child's unscientific mind."[34(a)]

It is recalled that the Committee of Ten in 1893 made mention of the inclusion of some physical science in the grades. Apparently this recommendation had little effect on the nature of the offerings in the elementary school. It is interesting to note, however, that in a course outline given by Flora J. Cooke for the Francis W. Parker school, "Elementary Physics (evaporation and condensation)" was included for grade 6.[3]

Some reasons which may account for the lack of physical science in the curriculum are: (1) the lack of adequately trained teachers, (2) biological materials were more accessible, (3) the psychology of learning of the time, (4) the machine age had not as yet made its indelible imprint on the world. There seemed to be little need for physical science. Schools were, by and large, located in agricultural areas and the important need was the study of plants and animals.

The fact that nature study was included in the schools does not indicate the absence of dissatisfaction. Some of this dissatisfaction is evidenced from a statement made by Professor William Hallock in 1905. "The purpose of this paper (presented by

Hallock) was to show that if nature study can be taught to advantage in grammar schools, then physical science also is appropriate there. Experiments with a magnet and iron filings are as well suited to arouse the interest and curiosity of children as is the study of an animal. The directive force of the compass needle is no less interesting than the ability of a toad to jump, while stories of how this force has been of help to marines would prove to be as instructive an interesting as those stories told about animals. . . . Many topics taken up in nature study are too difficult and should be preceded by the principles involved."[34(b)]

In spite of the Committee of Ten and the recognition of the shortcomings of the nature study idea by some, it continued to flourish through 1910. Otis Caldwell wrote a review of L. H. Bailey's book, *The Nature Study Idea,* in 1910 in which he stated, "Since 1903 nature study has secured a rather firm hold in many schools, and indeed it may not now be said to be a question as to whether the subject will be taught in the schools, but just what shall be taught and how shall it be taught. The subject is pretty well recognized as one that has come to stay. . . . The school garden as a laboratory for the nature study work has become pretty well introduced and this subject is given more and better recognition."[34(d)]

The effect of the continued development of the new education is evident from the studies of children's interests. The belief was, and is to the present date held by many, that children's interests should be the primary factor in determining curricular content. Some of the interest studies that had reference to science interests were: Mau (1912), Downing (1913), Trafton (1913), Finley (1921), and Pollock (1924). The interest studies seemed to indicate that the primary interests of elementary school pupils were in plants and animals. However, there was some interest in physical science indicated. It should be pointed out that this was the time just preceding and just following World War I and that machines were playing a more important role in the lives of men. Nature study, nevertheless, continued to be the science of the elementary school until long after 1930. The name had again changed back to elementary science in

some places around 1918 and since. It is said that there was a decrease in the amount of anthropomorphism employed by the teachers and an increase in the number of pictures rather than objects used by the teachers. The nature study idea is still enjoying considerable popularity in many schools in 1950.

The modern psychology of learning was developing, and now the learning and development of children is considered, by nearly all psychologists, as gradual and continuous and parallel to one another. It was found that the child reasons even in his pre-school years. This fact, known for some years before 1930, should have had some effect on the content and methods of teaching in the elementary schools.

It is said that Craig put forth the first real attempt to define a curriculum in science for the elementary school. Craig's study, *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann School,* published in 1927, has had wide influence. Craig wrote in 1929, "The field of natural science under the caption of nature study, although one of the infant categories of the elementary school, is probably most restrained by tradition. It has been hindered in its progress by the peculiar aesthetic and ethical philosophy which was created as its guiding principles by the nature enthusiasts themselves. . . . Nature study has been influenced little by the progress that has been made in the fields of measurement, techniques of teaching, psychology, and curriculum revision. It has remained comparatively static in the elementary schools and today its very presence in the curriculum is being challenged by many educators."[34]

Further evidence of the failure of nature study to meet the needs is found in the fact that a committee was appointed by the National Society for the Study of Education in 1930 to study science in the schools. The committee's efforts resulted in the publication of the *Thirty-first Yearbook.* This publication outlined an approach to the solution of the problem. The program advocated by this committee has given much direction and impetus to the teaching of elementary science. Craig played a very significant role in setting forth the ideas included in this

report. Emphasis was placed on a continuous unified program aimed at developing an understanding of the significant ideas in science.

During this early period the movement stressing organized subject matter in the secondary schools was affecting science in the elementary school. The emphasis was placed on mastery of a given body of subject matter rather than upon pupil needs and interests.

These two forces, organized subject matter and nature study, have been effective in determining the content and method of science in the elementary school. The *Thirty-first Yearbook* recognized the conflicting forces concerning the content and philosophy of science teaching. The purpose of science in the elementary school was stated, in this report, as that of all other subjects—that of assisting boys and girls to become educated laymen. This report included both the biological and physical sciences in the elementary school.

Several series of elementary science textbooks, referred to by some as elementary science readers, appeared after the publication of the *Thirty-first Yearbook*. The claim of some of these series was that they were based on the recommendations found in this report. Courses of study were written and rewritten in many places so as to meet the recommendations found in the Yearbook.

The recommendations of the *Thirty-first Yearbook* committee concerning the understanding of "big ideas" has been interpreted as still another approach to determining the curricular content in this area. The effect of this Yearbook is recognized in present day curriculum planning.

A study reported by Weller, *et. al.*, concerning the status of science teaching in the elementary school in 1933 reveals some astounding facts. "Only in seven, or 4.1 percent, of the 172 systems canvassed was there a special teacher of science for grades one to six; in all cases the schools had over 500 enrolled. . . . Nearly three-fourths of the schools (73.2 percent) had the conventional type of organization where one teacher teaches all academic subjects.

"Many types of teaching plans were used. The majority by far (56.8 percent) used the unit plan. Because of this, it was difficult for many principals to estimate the amount of time spent per week in each grade on science, but, of those reporting approximations, the average is 72 minutes per week.

"A science classroom was reported in 20.4 percent of the schools, and 22.1 percent have a science museum.

"There was a wide divergence in types of courses of study in use. . . .

"In response to an item that asked what devices or methods operated most successfully in their science teaching situation, we received approximately equal numbers of returns on various methods with the project method leading. Reading and discussion were used by 50 percent, experiments by 45.2 percent, project method by 59.2 percent, trips by 43 percent, reading and research by 27.3 percent, and many wrote in "pictures" and other methods. These lumped together amounted to 8.1 percent. This shows definite progress away from reading and telling of science stories as the only means of science instruction in the classroom. In 18.6 percent of the schools reporting, there was no definite instruction in science."[40]

The teaching of elementary science continued to grow, as evidenced by the fact that, in 1935, Mary Melrose reported that there was a science room in practically all the elementary school buildings in Cleveland.[19]

In 1942, the National Committee on Science Teaching of the National Education Association issued several reports recommending that curricular content in science be based upon social-personal needs. The workers on these reports received considerable guidance from the publications of the Educational Policies Commission. The National Committee on Science Teaching reports include statements of the needs of individuals in health, recreation, safety, work, conservation, in a maturing philosophy of life, socio-economic action, maturing inter-personal relationships, and intelligent consumership, and arranged them according to grade levels.[22]

The extent of the influence of these committees and reports

as well as the American Council on Elementary Science and the Progressive Education Association publication *Science in General Education* is difficult to determine. However its influence is generally acknowledged.

Elementary science is still looking for that *ONE* answer. The *Forty-sixth Yearbook* reemphasizes the need for more science in preparation for living in our democratic order. The objectives of science are restated, and emphasis is placed on their realization.

The fact that elementary science has not matured and is still growing is evidenced by a study completed by Pella in 1948. "A thorough study was made of the five most widely used textbook series in elementary science in order to determine what content was included in each text in each grade, what agreement existed among the five series at specific grade levels, and what agreement existed when grade levels were abandoned. "It was found that the greatest degree of agreement concerning the concepts presented was in grade 1 where 58, or 12.89 percent, of the 450 different concepts presented appeared in four or more series. There was a total of 8913 different concepts presented in the five series in the six grades after all repetitions were removed. Differences in the grade placement of the concepts in the five series was common as evidenced by the fact that 1464, or 16.43 percent, of the 8913 concepts appeared commonly in four or more series when adjustments were made for differences in grade placement. Approximately 60 percent of the 8913 concepts presented were devoted to the biological sciences."[29]

Elementary science is looked upon today as something more than knowledge about science, yet it is not well defined. The objectives of science for the elementary school child are described in terms of child development. The real science course today presents science as the agency that produced the modern world. It includes problem solving, experimentation, social implications of science, the use of the scientific method, the scientific attitude, research, manipulative skills, etc., in addition to knowledge of facts.

A variety of methods are found in the elementary schools of

the nation. In some schools, elementary science consists of a study of plants and animals. Some include plants, animals, health and safety, and physical science (even some chemistry).

The methods employed are probably as varied as the content included. Reading, no doubt, holds a position of priority in teaching science. A good guess would be that more pupils read about science than study it in any other way. Some schools are known to have pupils carrying on research, that is, research in accord with their own level of development. Some schools provide demonstrations, field trips, and many include movies, slides, film strips, and pictures.

Elementary science is today confronted with several problems. Some of the problems are the result of social and technological development and some are the result of the inertia of the past.

Question number one to be solved in the future is, "What should be included in the elementary science program?" This is a problem of content and is variously attempted by four different groups. There are those who belong to the nature study school of thought. There are those who stress the interests of children as the determining factor. There are those who look to the needs of children, both present and future. There are those who look to organized subject matter and its cumulative development.

If the first question is ever answered, the second may be attacked. "Where shall this content be presented?" This is a problem of grade placement and is subjected to the several psychologies of learning and philosophies of education.

Question number three is, "What kind of physical equipment do we need in the elementary school in order to most effectively teach science, and how can we get it?" Laboratory facilities are certainly needed if any level of achievement above verbalization is to be accomplished.

The last question is one that will probably be mentioned when the centennial year is celebrated by the Central Association of Science and Mathematics Teachers. "How can we more effectively train teachers in both methods of teaching and con-

tent?" Some teacher training institutions ignore the area of science and some recognize it by allotting time to read a book on science. The elementary teacher must have an opportunity to perform and discover, to search and experiment, to manipulate and develop. The elementary teacher must be aware of the basic philosophy of science, including its methods and purposes.

After we have the content, have it placed, have a physical plant that is adequate, and have a teacher adequately trained to use it all, we shall have achieved perfection only temporarily. The content and methods must continue to change with the changing culture of civilization.

Geography

At the beginning of the nineteenth century, the content of geography was very simple. It consisted of unrelated facts about the earth and its people. Emphasis was on location. Great quantities of encyclopedic material were memorized. As our country expanded and developed and the influence of such men as Darwin, Spencer, Agassiz, and Petzalozzi was felt, text books gradually changed in character from the encyclopedic to the descriptive and genesis treatment. In 1900, Tarr and McMurray made text book history with the introduction of the human element into the subject of geography which had been essentially physical in content. However, in the common schools throughout the country, various outdated methods were still in general use.

In 1902, the National Society for the Study of Education issued its First Yearbook on *The Progress of Geography in the Schools*[23] with W. M. Davis of Harvard University as author. This yearbook deplored the memorization of unrelated facts and locations which was still in vogue. It quoted from the report of the Committee of Fifteen of the National Education Association to the effect that geography, one of the most important subjects in the common school, is an intermediary science. It is, they claimed, a conglomerate of a number of sciences—physical,

natural, commercial, mathematical, historical—and has as its function the correlation of these various sciences with the arts. The yearbook emphasized that geography should be the study of the relationship between man and both his natural and his cultural environment. It urged the establishment of departments of geography in colleges and universities on a status comparable to that of the other sciences long thus established. It was felt that only when geography had been developed as a science would it be possible to select proper areas of the subject for each of the grades and the high school. It warned that if geography failed to consider the relationship of man to his environment, it would itself fail in its function.

Thus we see that at the beginning of the present century geography was recognized as a science and its dual nature had been pointed out by leading geographers. Geography, they had explained, is rooted in man's natural environment, but its finest expression lies in giving meaningful understandings of the relationships between the natural and the cultural environments of mankind.

Need for Reforms

However, in the first quarter of this century geography, as taught in the common schools and in the high schools, did not develop along these desirable lines. Instead, highly technical courses were offered, particularly in the high schools. The highly specialized content of these courses often included material taken from college courses. There was little the child could understand or that could ever be used by him. Physical geography, offered in the ninth grade, was diluted college geology. Land forms, their genesis and evolution were studied in great detail. Profiles of far away places the pupil could not visualize were made from topographic maps. Detailed but impractical studies of maps were often made. The home landscape, crying for recognition, went largely unnoticed. In the text books there was almost no reference to man's relation to his environment and little about its effect upon him, and when such material was included in the text, it was ignored by most teachers. In commercial

geography numerous statistics on production soon to become out of date were memorized, maps were copied, and other outmoded methods were employed. Slight, if any, attention was given to the meanings and implications of the statistics. A few teachers conducted trips through local industries, but any improvement thereby achieved was usually lost when another teacher without a full program, perhaps a language teacher, was assigned the class in commercial geography the following year.

Geography was not alone in this over-specialization of subject matter. In the *Thirty-first Yearbook* of the National Society for the Study of Education, Part I on *A Program For Teaching Science*,[25] published in 1932, it is pointed out that during the first part of this century a great variety of highly technical courses in the various sciences came to be offered in the upper grades and particularly in the high schools. This period has gone down in history as the time when the subject was taught, not the child. It may have resulted from the erroneously called "scientific movement" of the previous country. It may have been a response to the needs of a beginning industrial era. But whatever the cause, the significance of this yearbook was its departure from emphasis on subject matter. It successfully advocated a science program more in keeping with the needs of the child as he adjusted himself to an enlarging environment and the technology of a scientific age.

During the period of subject matter specialization, our country was undergoing an unparalleled development and expansion. This was influencing every phase of our culture. Our rapidly increasing population was being concentrated in urban areas. Removal from proximity to the land into crowded cities was creating leisure and a degree of social unrest. Immigation of peoples requiring assimilation was creating problems. The high school was making a phenomenal growth. Rapidly advancing technology was making demands on our educational system for a less specialized and more practical and functional education for our youth. Educational objectives were becoming more centered on the child and on helping him understand

his environment. Community projects such as school gardens, 4-H Clubs, and other extracurricular activities were being developed. Sectionalism within our country was beginning to break down under the impact of industrialism and a more general exchange of commodities and increase in travel within our borders. However, our economic development had not yet affected our traditional policy of isolation from the affairs of the rest of the world.

Although the high school was growing rapidly and becoming a second school for all children, parents felt that the kind of education their children were receiving was not the kind needed to fit them for life. Particularly in high schools, pupils revolted from the technical courses so far removed from life by dropping out of school. Statistics show that pupils dropped out of school at the end of the first and second years of high school at a very rapid rate. In the more progressive areas, enrollment in the newly organized courses in general science and in social science was increasing. Trends in enrollment in the physical sciences showed a decided falling off between 1910 and 1928 with physical geography leading in this decrease. Whereas in 1910 nineteen percent of the pupils were enrolled in physical geography, in 1928 only three percent were studying this subject.[25] This marked decrease in physical geography indicated the extent to which general sciencse had displaced it as a freshman subject. In the elementary schools, elementary science was beginning to replace nature study, and some phases of geography and education at that level was also becoming more functional.

Curriculum Problems

The organization of curriculums in these new science courses was a great problem. The science of education was far from mature. Conservatism, self-interest, emotion, heat—not light—at times obscured the real progress being made to help the child gain meaningful understandings. Another great problem centered around teacher training. The teachers of the displaced subjects had to be used. One could sometimes hear such a teacher say, "It is called general science, but what I'm teaching

is physical geography." However, the more progressive teachers welcomed the new subjects and became enthusiastic supporters and workers. Careful studies as to methods of presentation were made. Gradually the unitary organization, introduced by Morrison and set up around problems the solution of which would afford meaningful understandings, came to be considered desirable practice. This, along with the concentration on the child rather than on subject matter was a tremendous step forward in the teaching of all the sciences, not general and elementary science alone.

The social sciences appeared in the elementary schools and as introductory courses in the high schools replacing the over-specialized, far-removed-from-life courses in the fields of history, civics, the constitution, and geography. These new courses were designed to provide the child with greater understanding of the working of his own community and its relation to other human societies, and to make him more aware of his obligations and duties as a citizen in a society rapidly increasing in complexity. The *Twenty-second Yearbook* of the National Society for the Study of Education, Part II (1923) on *The Social Studies in the Elementary and Secondary School,*[24] prepared under the direction of H. O. Rugg, presented the need for the new social science courses, showed how the new curriculums were being developed, and proposed certain subject material for different grade levels. It pointed out that in many school systems the new subject had not improved greatly on the special courses it had displaced. Frequently the content of the social science course was lifted bodily from history or civics, but not often from geography. There was a tendency among social scientists to think that geography consisted only of memorizing the locations of places. This yearbook reported that too frequently the subject matter of these courses was not organized according to the best scientific criteria of the period. Too often, as in the case of general science, it represented the field of specialization of the teacher. However, in more progressive areas, intelligent curriculum revision had begun. Experts in several fields were cooperating with those teachers most interested in the new

courses. Of this yearbook, Frank M. McMurray,[24] in his critical appraisal of it, said that the abandonment of the encyclopedic point of view in curriculum making, the acceptance of the problem as a unit of organization (proposed by Rugg), and the recognition that practice as well as theory be provided in the problems selected would greatly influence educational practice. Progress, he felt, had been made.

What had happened to the subject matter that had been called geography? In schools where it had been displaced, some of its subject matter was enriching the new courses in elementary and general science and in social science. In some high schools, physical geography was moved up into a later year and offered there as a special course. Commercial geography continued in the commerce courses of high schools. Although both of these courses tended to perpetuate the evils of the subject-specialization era, in many areas progress was being made in a wiser selection of content and improved methods, including the introduction of field work, and greater emphasis was placed on relationship of man to his environment. Conservation of natural resources received considerable attention. Any improvement in the character of the content of these special courses was due to the increase in the number of departments of geography in colleges and universities and the influence of college teachers on prospective teachers enrolled in their courses. Many text books written by college teachers for use in elementary and high schools placed greater emphasis on the teaching of the functional phases of geography. In addition, The National Council of Geography Teachers had become an influential organization of the teachers themselves.

Beginnings of Reforms in Organization

In the nineteen-twenties, larger groups of geography teachers came under the influence of the developing science of education with its new knowledge concerning the laws of child psychology and the nature of the learning process and were using the new devices designed to secure more accurate scientific measurement of educational values of content material and of

method. Their work culminated in 1933 with the publishing of the *Thirty-second Yearbook* by the National Society for the Study of Education, entitled *The Teaching of Geography*[26] It was prepared with the cooperation of The National Council of Geography Teachers. Such authorities as Parkins (chairman), Parker, Ridgely, Stull, Lackey, Thralls, Grossmuck, and Brown were authors of the chapters. In this, the first yearbook on geography since 1902, the case for geography for grades 1 through 12 was effectively presented. There is revealed the tremendous amount of detailed work that groups of geographers had been doing down through the years to evaluate by the latest scientific measurements of their periods the content of geography and to assign appropriate subject areas to each grade level. They developed the many tools and devices needed for the enrichment of text and supplementary material and for improvement in method. They investigated the content of the social science courses of that period and found very little geography except in a few "fused" courses at junior high school level. Even in these courses, based on the problem method suggested by Rugg, they found far more stress on history and civics than on geography.

Space does not permit more detail about the excellent work being done by geographers at the time of the publishing of this yearbook. It has influenced both geographers and social scientists since that time. It is to be regretted that there was not more cooperation between these two groups at this period. However, each group was making progress along its own line.

In a certain sense, this excellent work in developing geography along desirable lines and proving the high social value of its content came too late. Elementary science, general science, and social science continued to hold their places in the curriculum. Perhaps this was not so much because their early content had been superior to that of geography as because they seemed more practical, more in keeping with the technology of the era, and in closer contact with everyday life and the social problems of the period than did geography.

There are a number of factors that tend to explain this sec-

ondary state of geography in the schools throughout the country even though such splendid work was being done by leading groups of geographers. One factor was the poorly trained or untrained teacher. Almost anyone, it was thought, could teach geography, and almost anyone did so. Few teachers had the training necessary to develop courses in geography. Then, too, educational statistics indicate that in most schools geography was only one among several subjects for which the teacher had to prepare each day. Therefore the teacher load was another factor. Lack of intelligent supervision was an important factor. A basic factor is to be found among the college and university teachers themselves. Many of them were largely, even exclusively, occupied in developing geography as a science and in turning out trained specialists in geography for the many and important demands industry and the government were making. While this work was very necessary and important for the best interests of our country, it made it impossible for these experts to give adequate attention to the needs of geography in the elementary and secondary schools. However, there was a group of geographers deeply interested in the problems of the public schools. It was their work that culminated in the second yearbook on geography previously mentioned. Teachers organizations must also bear some responsibility for the decline of geography in the public schools. For a large part of the first half of the twentieth century, organizations of geography teachers themselves made one fatal blunder which is characteristic of many subject matter groups of teachers. They ignored the fact that increasing complexity of society was making ever-increasing demands on many other subjects as well as upon geography. They planned geography curriculums as though they were to be given a major fraction of the pupil's time through the upper grades and the high school. Their lack of reason in this respect discredited them and the good things they asked for suffered as a result.

Three groups of organized teachers were asking for a large part of the pupil's time between grades 1 and 12—science teachers, social science teachers, and geography teachers. There was

not enough time for all. There was not enough cooperation between the interested teachers. Those who had been first with their programs held their places in the curriculum, and geography as a subject tended to disappear.

Interdependence of Social Science and Geography

In the nineteen-thirties, some groups of geographers and social scientists realized that they had something in common, namely, that each of their fields was indispensable in the effective solution of modern world problems. These groups began to work together. Since that time, there has been developing a greater and greater emphasis on education for social living. Two yearbooks recently published reveal this trend. One, published in 1947, is *Science Education in American Schools.*[27] It covers the field of the sciences and its significance lies in the strong support it gives to education for social living in an increasingly complex society. The other yearbook, published in 1948, is *Geographic Approaches to Social Education.*[41] This is the Nineteenth Yearbook of the National Council for Social Studies, a department of the National Education Association. They published this yearbook with the cooperation of the National Council of Geography Teachers, the Association of American Geographers, and the American Society of Professional Geographers.

Editor Clyde F. Kohn of Northwestern University states in this Yearbook that an academic understanding of the importance of education for social living is not enough, and that only if teachers provide learning experiences which will give children many opportunities to understand their own everyday affairs and those of other peoples can a geographic point of view be attained. He believes that the geographic point of view is absolutely necessary in the solution of world problems and that to achieve this result it is now quite obvious that the relation between science, geography, and the social sciences must be taken into consideration when courses of study are planned.

The Contributions of Geography to Solution of World Problems

In this yearbook, Preston E. James of Syracuse University[41] writes: "Geography has a role to play in peacetime which is

as fundamentally important as the role it plays in war time. During two world wars, the demand for more geography and more geographers to instruct everyone from third grade children to generals and admirals has been notable. But between the wars the decline in attention given to geography in the schools was accompanied by the return to isolationism, the attempt to build a self-sufficient America with a minimum of connections abroad, the denial of responsibility in the international field, and by the erection of barriers to the international exchange of goods. The decline in attention given to geography may have been a result of the same social attitudes which built the spirit of isolationism, but it is not unrealistic to suggest that it may also have been a contributing cause of America's tragic withdrawal."

And again, he says: "There are at least four ways in which the subject matter of geography sharpens our concept of that rather vague thing called 'world-understanding,' and in these four ways geography makes a contribution which is unique among the social studies. (*a*) Geography presents an effective treatment of the land factor in the study of man-land relations; (*b*) geography places emphasis on the significance to man of differences which occur from place to place on the surface of the earth; (*c*) geography teaches the reading and understanding of the map; (*d*) geography develops the capacity of out-of-door observation. Geographers, who, of course, do not do any of these things well enough to be self-satisfied about it, nevertheless bear chief responsibility among the social studies workers for developing these fields." He continues, geography "has certain basic aspects to develop regarding man's relation to the earth. These concepts are derived from all the social sciences, not from geography alone; yet they should form the core of geographic education from elementary grades through the graduate school. Only by stating and restating these concepts, and by illustrating them again and again with important examples, can a proper understanding of the problems of man-made relations and conflicts between states and societies be gained."

Edith Putnam Parker of The University of Chicago, who has been an outstanding leader in the determination and solution

of the problems of geography in the public schools describes the kind of education needed as follows:[41] "In view of the great complexity of critical problems that face humanity today, both teachers and students need various kinds of knowledge as a basis for accurate thinking and wise action relating to those problems. Like all other citizens, they need knowledge of the roots of critical problems—local, regional, national, and world problems—which obviously confront us. They need, for instance, knowledge of different cultures, of social phenomena, of the nature and functioning of social, economic, and political institutions, and of the *meanings* of all these things in our lives. They need knowledge of the stages in the development of our civilization and of *meanings revealed* by historical analysis of the life and significant actions of specific groups of people in given periods of time. They need knowledge of the *meaning* revealed by geographical analysis of complexes of people, man-made features and natural features which exist on the surface of the earth. No amount of knowledge of any one of these various kinds of meanings can possibly result in the kind of insight into human problems which we all need, for each kind has a distinctive role to play in gaining that insight.

"Mere knowledge, moreover, is of value to us and the young people under our guidance only as it is used in reaching accurate conclusions needed as a basis for deeper insight and wise action. We need experiences which help us to overcome the tendency to act on the basis of emotions instead of on the basis of reasoning. We need, accordingly, to gain steadily, through abundant experience in the exercise of our reasoning power, the ability to do accurate thinking based on reliable and adequate data. Judgments which, though carefully reasoned, are based on only part of the data which need consideration often result in prejudices even more difficult to cope with than are prejudices based on emotion.

"In discussing differences in problems which people face in different localities, it is essential to avoid giving the impression that people *must* do what one finds them doing. If human beings were not possessed of reason and were not capable of

choice, there would be no point in social education. To see the reasonableness of doing in a given kind of place what one sees men doing there is a very different matter from looking upon what they do as the *only* things which it would be reasonable to do there.

"To clinch the idea that men in every locality make choices in their use of what they find there, one needs to have repeated experiences in observing localities having much the same natural characteristics, but markedly different in what the people in them are doing. Also needed are experiences which make it evident that in any given locality people change their ways of doing from time to time as they develop new desires, new technology, and new insight into potentialities."

In conclusion she says, "One can possess much geographical information without having developed a geographic point of view and without having gained that insight into human problems which comes from seeing differences in problems and in ways of coping with them in different localities and regions."

Wallace W. Atwood, late president emeritus of Clark University, reminds us in a chapter on Fostering International Understanding[41] that we are moving rapidly into an era of world consciousness and that all citizens in order to vote intelligently should now have an intelligent understanding of the living conditions and the principal problems of their own country and of each of the leading countries of the world. He points out that our government appreciates its need for further geographic information by calling greater numbers of geographers into public service and sending some back to the universities for graduate study, and that 800,000 teachers have been alerted by the National Education Association to keep the development of "worldmindedness" before them as one of the prime objectives in whatever courses they may be giving. The late Nicholas Spykman of Yale, Atwood says, wrote: "Geography is the most fundamental factor in the foreign policy of nations." Atwood believed that ignorance of basic understandings of world problems should disqualify a man for public office in the field of international relations.

If the goals set forth in this yearbook on geographic approaches to Social Education are to be realized, the curriculums involved will require adjustment and revision. Teachers will need to be trained in the fundamentals of the sciences, geography, conservation, mathematics, history, the social sciences, and the humanities. They will need more adequate training in psychology and in the application of new methods. In the solution of these problems we start at the middle of this century with the goals of education more clearly defined and more generally accepted than were those at the beginning. The science of education has developed rapidly and is now of greater aid in evaluating the significance of our progress than formerly. In the organization of curriculums, the importance of the cooperation of teachers of different subject areas is now realized. Geography has advanced in position in that it is now recognized that the attainment of the geographic point of view is one among a number of indispensable factors in the solution of human problems.

Opportunities for the integration of significant geographic material into other courses are now being provided in those schools which have become concerned with the quality of contemporary living. Courses in the sciences, the social studies, history, economics, health, and conservation are being thus enriched. The time is surely not far away when the teaching of the geographic point of view will receive merited attention in the organization of curriculums from the elementary level through the graduate school.

In conclusion, we repeat that mere knowledge of geographical facts does not in itself have influence in the solution of human problems. Only by providing more and more experiences in understanding the problems of human societies can the school experiences of children be integrated into understandable life patterns.

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The Preparation of Teachers

At the turn of the century, teaching in secondary schools in the areas of science and mathematics, as well as in other subjects, was greatly under the influence of the Report of the Committee of Ten[11] and the then current faculty psychology and doctrine of formal discipline in the early 1900's. To utilize science and mathematics to train the minds of boys and girls and thereby to prepare them equally well for college or for vocational work, it was thought that teachers needed only to have a background in subject matter. The term "training" as applied to teachers was probably quite accurate, in the sense that they needed to go through courses where emphasis was placed upon the formal and systematic study of subject matter in order to be able to present it similarly to secondary school pupils.

Preparation of Teachers

Meticulous classification of plants and animals, accurate detail in quantitative laboratory experiments, logical organization, and "theoretical" types of problems all were supposed to have disciplinary values contributing to the training of teachers, who in turn stressed these activities with pupils. Few requirements other than courses in the field to be taught were deemed necessary for secondary teaching. One needed only to know mathematics or physics to teach these to boys and girls. In

many cases, it was deemed necessary to have no training in a subject beyond that attained in high school; one could teach physics to high school students if he had had a course in high school physics. Since a subject was to be taught in the same amount and same way for all, there was little need for a knowledge of individual differences or other aspects of children, learning, psychology, or method.

By 1900, the high school as an institution in the United States was only 80 to 90 years old, and had only recently been replacing the earlier academies. The increasing enrollment in these "people's schools" had placed greater demands upon the colleges for high school teachers. This demand was making itself felt in the type of preparation as well as in the number prepared. For example, in the Pennsylvania State Normal Schools, the state school laws provided in 1885 that there should be offered three distinct courses of study: elementary, scientific and classical.[5] These courses were organized as follows:

Elementary

1. Language—Orthography, Reading and Elocution, English Grammar, Composition, Rhetoric, Elements of Latin.
2. Mathematics–Mental Arithmetic, Written Arithmetic, Algebra, Geometry.
3. Natural Science—Political Geography, Mathematics and Physical Geography, Physiology, Natural Philosophy, Botany.
4. History—History and constitution of the United States.
5. The Arts—Penmanship, Drawing, Vocal Music, Bookbinding.
6. Teaching—School Economy, Methods of Instruction, Mental Science, Methods of Culture, History of Education, Practice of Teaching.

Scientific Course. Above, and also

1. Language—Rhetoric, Composition, Literature, English, Classics, Latin.
2. Mathematics–Higher Algebra, Trigonometry and Surveying, Analytical Geometry, Differential and Integral Calculus.
3. Natural Science–Geology, Chemistry, Zoology, Optics, Acoustics, Electricity and Galvanism, Analytical Mechanics, Astronomy.
4. History—General History.
5. Arts—Vocal and Instrumental Music.
6. Teaching—Mental Philosophy, Moral Philosophy, Logic, Lec-

tures on the History of Education and Philosophy of Education.
Classical. Above, and also "usual collegiate course in Latin and Greek."

Such early provisions for professional curriculums for science and mathematics teachers were soon followed by special courses which were the forerunners of our modern special methods classes. One course at Clarke University was described as "primarily shaped to meet the special needs of two classes, one composed of those desiring to qualify themselves for professorships of pedagogy in universities, colleges or normal schools, the other class composed of those who intend to become superintendents of state or city systems of education or wish to fit themselves for other administrative systems."[6]

The description of this "Special Pedagogy" course was:

Chemistry

1. Lectures (5). Topics: Methods of Teaching Chemical Science.

The history of the development of modern methods. Fit adjustment of theoretical and experimental teaching and the value of each as modes of mental discipline. How far chemistry can profitably be taught in the secondary and primary schools. Best means of securing enduring results. The best and most economical ways of installing and furnishing a school laboratory, and the precautions required to insure profitable and safe work from immature students. Suggestions on the preparation and delivery of experimental lectures. The best system of teaching the three main branches of elementary chemistry, viz.: general descriptive chemistry, mineralogy, or the natural aspects of chemistry and quantitative chemical analysis.

Science Laboratories in High Schools

The use of the laboratory in high school teaching, probably given its start by Leibig in Germany around 1826 and furthered by Agassiz around the middle of the century, was rapidly gaining momentum. It appeared in high school science courses about 1889 and by the turn of the century apparently had been widely adopted, particularly in the teaching of chemistry. Probably there was more than mere coincidence in the general acceptance of the laboratory in high school science teaching and the appearance at about the same time of college course offerings for high school teachers. Perhaps both resulted from a growing

recognition of the role of science in living and of the necessity for the preparation of teachers who could use the methods and materials of science with pupils.

Early Courses for Preparation of Science Teachers

As early as 1888, college catalogues indicated that some provision was being made in colleges for preparing science teachers for high schools. In this year, the catalog of Ohio University stated:

> Those who have completed the pedagogical course satisfactorily will receive diplomas. Students in the pedagogical course will also be expected to teach, under competent supervision, during their connections with the institution. The study of the natural sciences will be made practical so far as possible, and the construction of some simple apparatus will be so taught that even the teachers in the country schools, who have had the benefit of this instruction, can illustrate the most important laws of physics and chemistry.

One of the earliest formal courses in methods of teaching science appeared in the Columbia University Teachers College catalog for 1893. A course was listed and described as follows:

> X. Methods of Teaching Science in Elementary and Secondary Schools.
>
> Discussions upon the methods of studying natural science with brief sketches of the lives and labors of a few eminent naturalists; a study of the movement of modern times toward introducing science teaching into the common schools: the inspection of schools where science is taught in the vicinity of New York; discussions of ways and means of teaching chemistry, physiology, botany, and geology under the present conditions in the public schools; observation of lessons given in the Horace Mann School by expert teachers; laboratory instruction in the art of experimenting and in the construction of home-made apparatus. Three hours weekly.

By 1899, this offering had been expanded to include two courses, one on "methods of teaching physical science in elementary and secondary schools," concerned with teaching of chemistry for the first half year and physics for the second half, and the second on "methods of teaching biology in elementary and secondary schools."

The Ohio State University apparently first made concessions

to the "pedagogic" aspects of science in the summer of 1895 when certain offerings were listed in the catalog. In mathematics, elementary algebra, elementary geometry, plane geometry, trigonometry, calculus, and advanced mathematics (college algebra, higher trigonometry, analytical geometry) were offered. Notation was made that "the work will be so conducted as to give preparation for teaching as well as practical knowledge of the subject."

For physics there was the following description:

A. Recitation and Demonstration in Elementary Physics. Five hours.
B. Recitation and Problems in General Physics. Five hours.
C. Individual experimental work, especially designed for teachers in connection with courses *A* and *B*. Laboratory fee, $1 extra. Five hours.

In geology, while there was no separate methods course listed, the description of the elementary course indicated that "it will be adapted to the needs of teachers of geology, physical geography, and natural history in common and high schools." Also in zoology, the description of the course on Anatomy and Physiology indicated that "the work will be especially arranged for those who wish more thoroughly to prepare themselves for teaching this important subject."

An interesting change is noted in the announcements for 1899-1900 in the Department of Education where the following course is listed:

69. A study of scientific Method: intended especially for those preparing to teach Science. Twice a week.

In the Ohio State University Catalog of 1902-03 is listed for the first time a professional course offered by the department of chemistry. The course is described thus:

36. The Teaching of Chemistry. This course is arranged for students who expect to teach chemistry in secondary schools. It includes a general discussion of the equipment of laboratory and supplies, methods of teaching, and related topics. Each student will spend two hours in conference and three hours in supervising the laboratory work of freshman students. The course is open only to ad-

vanced students and no student is allowed to take it except by permission of the instructor in charge. Professor McPherson.

It was not until three years later that the following brief listing appeared:

17. The Teaching of Physics. Prerequisite, two terms of college work in Physics.

The course was offered by the department of physics. Meantime a course in Methods in Zoology was also offered.

The University of Chicago, under the leadership of Wilbur S. Jackman, offered professional courses in the teaching of science at least as early as 1901 and 1902. At this time, the *Register* listed the following courses:

81*A*. Principles and methods in field study.
82. Pedagogical aspects of field and laboratory work in nature study.
83. Principles and methods of teaching biology, modes of presentation: theory and practice of teaching.
84. Principles and methods of teaching physics and chemistry. Place and aim of physical science in secondary schools.
85. The history of science teaching.
86. Organization of science work.
87. Experimental science in relation to simple typical industries. Consideration of the real relation of the growth of Science and of technical occupation to each other, with laboratory work elucidating scientific principles involved in some industries simple enough to be taken up in schools."

Apparently in many colleges and universities the need or advisability of special courses separate from the more general ones for teaching had not been recognized. At Cornell University, for instance, the only specific preparation for science teaching in 1899 was that integrated with the general course for teaching high school subjects. Its description as given in *The Register* for 1898-99 was as follows:

27*a*. Lectures on the Teaching of High School Subjects. These lectures are designed for students taking the courses in the Science and Art of Education. The following subjects will be considered: *Fall term:* Latin, Professor Bennett, five lectures; Mathematics, Professor Wati and associates, four lectures; Physics, Professor Nichols, four

lectures. *Winter term:* Civics, Professor Jenks, four lectures; Geography, Professor Van, four lectures; Rhetoric and English Composition, Professor Hart, four lectures. *Spring term:* History, Professor Tyler, five lectures; Botany, Professor Atkinson, five lectures.

It was not until 1914-15 that a separate course was offered for science teachers, and this was a combination of science and mathematics methods, described as follows in *The Register* for 1914-15:

12. The teaching of high school science and mathematics. Second term. Assistant Professor Fraser.

For elementary teachers, short courses in normal schools or even only a year's work beyond high school in a high school normal training department were provided. Here, also, some attention to and experience in working with children in the elementary school was usually provided.

Early in the century, there was some evidence of a shift from the emphasis on discipline and formal subject matter training. As early as 1904, Woodhull advocated the use of more demonstration lectures, fewer quantitative laboratory experiments, and the desirability of putting an emphasis upon applications of science through using "a great variety of machines which are superior to the laboratory apparatus for purposes of instruction."[21]

Preparation of Mathematics Teachers Early in the Century

In 1912, the Report of the American Commissioners was published; this stressed the need for better preparation for teachers of mathematics and included the following summary of preparation at that time:[16]

The present degree of preparation.—At present the strong newly appointed teacher of mathematics is a college graduate who has had a year's course in the calculus, with antecedent courses, making a total of from 180 to 360 class periods of collegiate work in mathematics. Usually he has had varying additional amounts of mathematical work, and occasionally he has had some training in the theory and practice of teaching the subject.

The average newly appointed teacher of mathematics is a college

graduate who has had only about one year's work (from 90 to 180 class hours) of mathematics beyond the work of the school in which he teaches.

The constitution of this year's work varies somewhat, but a typical combination would be: Trigonometry, college algebra, analytic geometry. The average preparation includes no strictly professional training, no course in the teaching of mathematics to initiate the candidate into the teacher's mode of viewing the events of the classroom. Consequently, he enters upon his work with but little mathematical knowledge in advance of his pupils, and with no training at all in the technique of the work he is about to undertake. He is essentially a former pupil, somewhat matured by the general experiences of his college studies and life, come back to teach his quondam fellows.

If successful in his work, he develops into a good teacher, at the expense of many mistakes, more or less numerous and serious, according to his measure of native aptitude for the work of a teacher. In exceptional cases he extends his mathematical attainments further by means of attendance on summer sessions of higher institutions, by private study, or by correspondence work. But it undoubtedly requires special enthusiasm and devotion to do this in addition to the heavy burden of teaching work generally carried.

It is obvious that this measure of preparation is entirely inadequate and that, while pioneer conditions may have required the toleration of such a state of affairs up to the present, the time is now at hand for the adoption of a radically different course.

Factors Influencing Change

In 1920, appeared the report of the Science Committee of the Commission on the Reorganization of Secondary Education[19] advocating that sciences be organized and taught to help achieve the "cardinal principles" proposed in its 1918 report; and in 1927 the report of the North Central Association on Standards[14] was issued. These stressed a more functional approach and the desirability of making instruction in such areas in the schools relate to all important areas of living in contrast to the previous narrow emphasis upon facts and discipline. While the implication of these reports for the preparation of science and mathematics teachers was not too specific nor immediately put into practice, they were early evident and gradually effective.

Changes in the school population, objectives, and practices

in the rapidly growing secondary schools of course reflected changes in the preparation of science and mathematics teachers, although the latter tended to lag considerably behind school practices, then as now. The "new" psychology, with its shift from training the faculties and from the dominant role of transfer of training, and its advocacy of "stimulus-response" had its effect upon the nature and planning of the school curriculum and upon courses in mathematics and science. This, along with the practical demands of the increasingly large numbers of students in the schools with their vocational needs and the outmoding of the belief that all pupils regardless of needs and interests should have the same amount and kind of mathematics and science, had a tendency to make these courses more practical and related to everyday living. New and more functional methods books which were interesting and attractive also contributed to the changing nature of courses. Job activity and analysis were utilized to determine both the important facts to be taught and the phases with which teachers should be able to cope. One study listed 1001 activities and skills for teachers.[2]

Conflicting theories and emphases, however, on the part of educational philosophers, psychologists, and administrators had the effect of creating a wide variety of practices rather than a common and concerted trend. Such leaders as Bode, Dewey, and Kilpatrick were raising questions about existing theories and practices and stressing the desirability of synthesis rather than analysis and the need for more attention to the learner, his environment, and basic drives. Such phrases as "the activity program," "the child-centered school," "the passing of the recitation," "learning by doing," and "the project method" will be recalled by any who taught in this period and suggest the emphasis which was being placed upon the individual and the group. Reflecting this conflicting picture and metamorphosis in science and mathematics teaching, Beauchamp, in connection with a national survey of education,[1] indicated that science teaching around 1930 was a rather confused mixture of the earlier theories and practices of the century and a variety of newer ones.

The report usually known to science teachers simply as the *Thirty-first Yearbook*,[12] appeared in 1932 and had considerable influence upon science instruction at all levels. The report stressed the part which science could play in a liberal education. It suggested a program for science from the elementary school through the junior college, and organized content and pupil experiences around the major generalizations with their associated scientific attitudes as contrasted with laws and facts of science as such. This report probably helped considerably to straighten out some of the confusion and conflicting practices in the science teaching of the period, and because of its influence affected the preparation of teachers, and perhaps because it was used to a considerable extent in preparing teachers, this contributed to its wider influence.

A growing movement toward the introduction of professionalized subject matter courses seems to have started around 1920[20] and gained some impetus during the next decade or so, particularly in normal schools. While it is not clear that there was agreement as to just what professionalized subject matter is or how such courses should be organized and taught, numerous leaders in science and mathematics education recommended and urged their increased use.

A summary of the research relating to analysis of existing practices in the preparation of science teachers around this time (approximately 1920-30) is given by Noll[13] who suggests:

1. There is a great diversity of course titles in curricula for the training of science teachers, but judging from other types of data accumulated by Van De Voort, Hurd, *et al.*, certain courses are commonly offered and may reasonably be assumed to represent much the same content.
2. There seems to be a trend toward the development of four-year curricula for prospective science teachers. Such curricula are almost universal in colleges and universities and increasingly common in normal schools.
3. Universities and colleges concern themselves predominantly with the training of science teachers for the secondary schools, while normal schools train teachers for the elementary schools. This is the traditional division of responsibility between the two types of institutions.

4. In normal schools a greater proportion of the courses offered are of the professionalized subject-matter type than is the case in universities and colleges.

5. Universities and colleges offer a greater proportion of courses in special methods than do the normal schools.

6. Courses in biology for prospective teachers are offered most frequently in all institutions. In universities and colleges, courses in chemistry have the second highest frequency, while in normal schools the same rank is held by courses in nature study.

7. On the basis of the 120 semester-hour requirement for a bachelor's degree, the universities and teachers' colleges specify the following requirements for science teachers:
   a. About 30 percent of the total requirement for graduation must be in pure science—physics, biology, etc.
   b. About 6 percent in each of the fields of psychology and general education.
   c. About 20 percent in professional courses taken altogether and including practice teaching, observation, etc.

The *Fourteenth Yearbook* of the National Council of Teachers of Mathematics appeared at about this time, stressing more desirable preparation of mathematics teachers and comparing the training of mathematics teachers in England with those of the United States.[18]

Legal Requirements for Teaching

State departments gradually set up increasing requirements for the certification of teachers of mathematics and science and other teachers. A general tendency in the early part of the century seemed to be in the direction of requiring a college degree, some student teaching, some professional education, and a few hours of college work in the subjects to be taught, or at least in "related" subjects. One study summarized the state requirements as follows:[15]

1. All states issue certificates.
2. Thirty-six states require a degree for certification.
3. Some states require a degree in certain cases and issue a license upon certain conditions in others. Those that do not require a degree in most cases issue licenses requiring a certain amount of college work, usually two or three years. A few states not specifying a degree issue certificates upon the basis of examinations.

4. About one-half the states require practice teaching.
5. Most states specify about fifteen hours in education, the range being from nothing at all to twenty-four.
6. Most states specify a certain number of hours of academic training in science. This varies greatly but is usually not less than five or six semester hours in the subject taught.
7. Approximately 50 percent of the states issue blanket certificates entitling the holder to teach any subject.

Apparently states, counties, local boards, and administrators found it difficult to obtain adequately prepared science and mathematics teachers. Evidently they considered it unnecessary that teachers have much, if any, background in the subjects to be taught, since numerous studies indicate during this period lack of subject matter training and lack of professional preparation, particularly in methods courses and student teaching. In a study of science teachers in Minnesota,[8] for instance, it was reported that the majority of 1024 secondary school teachers, having at least one class in science, did not have a major in science. Also, small schools with their need for handling several courses in science or other subjects particularly seemed to find it difficult to obtain qualified teachers. A report by the Committee on Subject Matter Preparation of Secondary Teachers[9] in 1938 recommended that reforms in subject matter preparation were needed and should be based upon a realistic understanding of the high school and its problems.

Influential Reports

In 1935, a commission of the Mathematical Association of America published a report in which it recommended specific preparation in both mathematics (and "related work") and also in education, including special methods and student teaching.[10]

Early in 1930, the Progressive Education Association set up a Commission on Secondary School Curriculum. This commission provided for the preparation and publication of a number of volumes which were variously received by teachers and administrators of the period. Among these were *Reorganizing Secondary Education,*[17] *Science in General Education*[3] and *Mathematics in General Education.*[4] Whether or not teachers

and other educators agreed with the suggestions for reorganization proposed, these had and probably are still having considerable influence in the science and mathematics programs of secondary schools. At least they called attention to needs of adolescents which were not being well met by existing programs and forced teachers to examine and explain their procedures and practices, as well as to tell how teachers were prepared to cope with these needs in the schools.

During this period of the early part of the century, a number of methods textbooks or similar books for science and mathematics teachers were published, tending at first to be in specific subjects and later for science or mathematics teachers in general. In general, these books tended to reflect changes in theory as well as in practices and to suggest ways of putting into practice some of the recommendations of recent committees and leaders. Numerous companies also provided an extensive array of usable charts, motion pictures, and apparatus for teaching science and mathematics courses.

Present Status and Trends

There has been a steady growth of organizations which are concerned with the improvement of teaching and teacher education. These organizations may be classified for present purposes into two groups. The first of these includes those organizations of rather general character which have been attempting to give leadership to colleges and departments of education through their publications and meetings, as well as other services. Typical of such organizations are the American Association of Colleges for Teacher Education, the Commission on Teacher Education, the Association for Student Teaching, and the Association for Childhood Education. These organizations, which in general represent nation-wide concerted efforts, have resulted from smaller local groups which have united for more effective action.

In the second group are those professional organizations concerned directly with the teaching of science in the elementary and secondary schools and with the preparation of teachers.

Examples of such organizations are the Central Association of Science and Mathematics Teachers, and the National Science Teachers Association. The memberships in these organizations have been growing, and the influence of each is extended through the media of publications, meetings, and services to teachers. Science teachers are finding more and more the desirability of their participation in such professional groups.

Another professional group which has concerned itself in the post-war period with problems related to the teaching of science and mathematics is the Cooperative Committee on Science and Mathematics Teaching of the American Association for the Advancement of Science. The committee, composed of representatives of various scientific and professional organizations, attempted to survey the needs of the present situation in public schools and in institutions of teacher education. They made a number of recommendations[7] for the preparation of teaching as well as for other aspects of teaching science and mathematics.

During the past fifty years it has been realized that teachers must grow while they are in service. A society characterized by evolving economic, social, and political ideas and ideals must be served by teachers who are able to lead rather than to hold to a *status quo*, or simply to follow. It became evident, as early as the third decade of the present century, that education was much in need of in-service improvement of teachers. This has been approached in various ways. One pattern has included a fifth year of college work, in some cases culminating in the master's degree. In a few states, permanent certification is withheld until the fifth year of college work has been completed. In some cases, this fifth year of work must include evidence of professional growth in order that the permanent certification be obtained.

The fourth decade of the century saw the origin of the workshop as a device for teacher education. At the present time, workshops are accessible to all teachers. Varying in length from one week to several, they provide opportunities for teachers to come together to discuss, read, confer with leaders, and to prepare materials for their own use.

Additional preparation in the form of in-service work is provided in many areas through extension courses from colleges and universities, summer school, and through group conferences. An interesting development of this type are the fellowships provided by certain of the large industrial corporations which are contributing to the education of science teachers for working and studying in industrial plants and laboratories.

There is a rather general movement in the improvement of the teaching of science in the elementary school. This has been based on an evolving conception of what should be taught there. The curriculum is expanding to include experience in the field of science, and for this purpose teachers should be prepared. In general, this means that all elementary teachers must know something about science, particularly as it relates to the life of the elementary school child, and must be able to teach this science to children. Colleges and universities are moving slowly but steadily toward the inclusion of science courses, both biological and physical, for the elementary teacher.

The preparation of teachers in the fourth and fifth decades of the half century has been developing on a broader basis than was true in the earlier years. The process has been sped by the recent war which has forced upon society a realization that teachers must do more than impart information. Particularly impressive was the realization that science and mathematics must be more effectively taught.

Educators have learned that science and the other subjects in the school curriculum are not isolated entities of subject matter but should be related as integral parts of the whole curriculum. With this recognition and with an increasing understanding of effective teaching procedures, it has become possible for both science and mathematics to become more meaningful in the lives of the people who study them.

The nature of the school population has changed in this same period of time. Graduation from high school is no longer considered primarily as a stepping stone to college entrance. Educators are coming to realize increasingly that the secondary school is a terminal education for approximately 80 percent of

the school population of the entire United States. They are coming to realize also that more than 70 percent of all people of high school age are now in high school. Thus it is essential to provide experiences in science and mathematics through which these areas will function in the lives of young people.

The realization of this changed school population and of the increased understanding of effective teaching procedures has resulted in a continuing emphasis on professionalization of subject matter. In some institutions, there is an increasing percentage of time allocated to professional courses, particularly those in the fields of special methods of teaching science and mathematics, in an effort to assist teachers to use the content of subjects more effectively in the teaching of young people.

There has been a gradual increase of time in the period of preparation of teachers, both elementary and secondary. This period of time tended to increase until the exigency of the war made it impossible to continue holding the standards which many states had been able to achieve. With the supply of teachers now tending to meet the demand, particularly in high school teaching, the period of preparation seems likely to increase in the next few years.

The preparation of teachers has been evolving slowly toward an experience curriculum. Courses in special methods are becoming increasingly functional by providing a more direct approach to the problems of teaching of science and mathematics. Whereas the descriptions of the methods courses offered in earlier years indicated a rather formalized approach to the teaching of science and mathematics, we find the present descriptions of methods courses in science and mathematics concerned more with professional problems. Here is a sample from the Ohio State University College of Education *Bulletin* for 1949-50.

Education 689. *Field and Laboratory Work for Teachers of Mathematics.* Three credit hours. Demonstrations, field work, projects, readings, laboratory work, and participation in University School mathematics classes. Recommended for students in the College of Education who are majoring or minoring in mathematics. Prerequi-

site, a major or minor in mathematics and Education 687 or the equivalent.

Actual experience with instruments and apparatus in field and laboratory work suitable for boys and girls in the junior and senior high schools. The use of devices and apparatus including the slide rule, the plane table, the alidade, the transit, the angle mirror, the sextant, the hypsometer, and clinometer for teaching concepts and skills needed in elementary surveying and mapping. Field and laboratory work and demonstrations will be carried out illustrative of teaching procedures applicable to secondary school classes.

These methods courses suggest an emphasis on experiences with young people for the prospective teacher and with the materials as well as ideas which are used in teaching.

The student teaching is often preceded by a period of directed observation which evolves gradually into participation in the activities of the school, the prospective teacher serving as an assistant to the regular teacher. This plan provides for an evolution from participation into student teaching. At no point is there a clear break in the relations which the prospective teacher has with the students and with the school in which he is being prepared.

There is a tendency to consider all other professional courses subsidiary to the direct experience with students. The range of this experience considered desirable is rather broad in various institutions. The usual school experience is supplemented by camp counselling, Boy Scout work, and social service and religious activities with young people.

There is an increasing tendency to encourage research in the preparation of teachers of science and mathematics. Various institutions of higher education have furthered this research through programs for graduate degrees and through studies of teaching. For example, studies in the teaching of science have been carried on by the General Education Board, and by the Bureau of Educational Research in Science. More recently a nation-wide effort has been launched to provide for a clearing house for all research in the teaching of science. This plan provides for the cooperative activity of various institutions and organizations with the Specialist for Science, Division of Second-

ary Education, in the United States Office of Education acting as secretary. The function of this project is to secure information on, and provide brief annotations of, completed research during each half year.

Needed Emphases

With the foregoing survey as a background and guide it seems appropriate to suggest some of the emphases which appear to be needed in the years immediately ahead. These are presented for consideration, discussion, and possible investigation. Obviously there is interrelation and overlapping among them.

1. Preparation of teachers in both academic content and professional experience adequate to the aims and purposes of the best schools and to the needs and development of boys and girls in our evolving society.
2. Preparation of mathematics and science teachers in such related fields as conservation, aviation, atomic energy, and consumer problems, of importance in the present or immediate future of boys and girls.
3. The development of more concern with the problems and resources of communities in the preparation of science and mathematics teachers, both in their pre-service and in-service experiences.
4. Provision for the in-service growth and improvement of science and mathematics teachers.
5. More first-hand experience with children and teaching problems and with procedures related to important goals during preparation for teaching.
6. Experience with the professional resources for science and mathematics teachers, including skill in using reading and visual materials, as well as devices and equipment needed by science and mathematics teachers in a modern program.
7. Provision for developing and evaluating competency in the various phases of science and mathematics teaching rather than dependence upon credit hours as an index of teaching preparation or effectiveness.

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